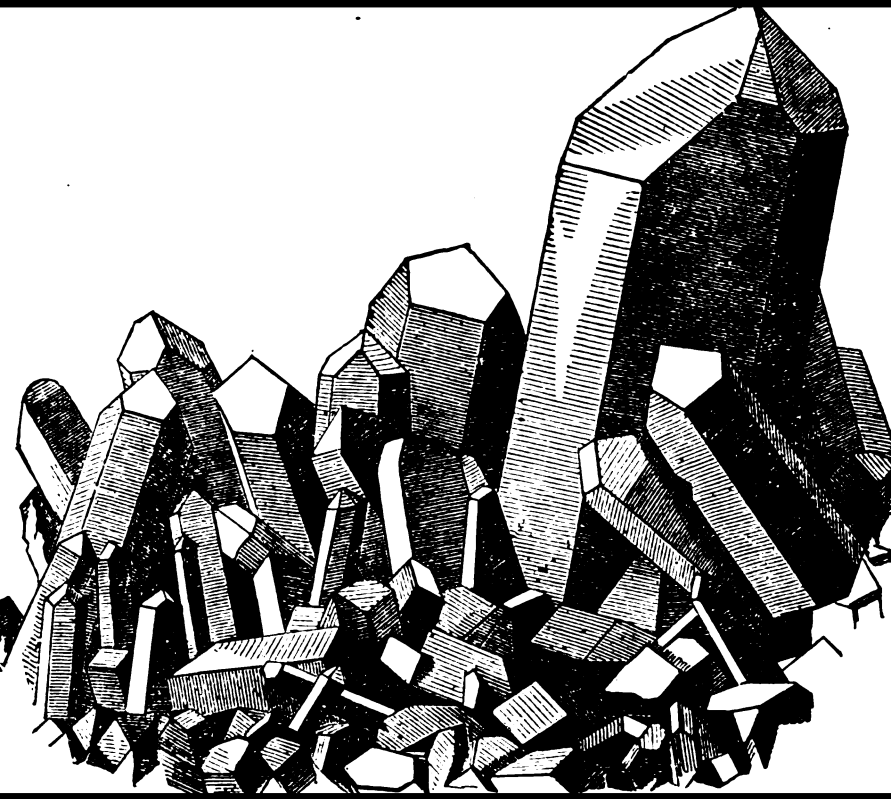

Elementary Geology of Tennessee

William Gibbs McAdoo, Henry Clay White

ELEMENTARY

GEOLOGY OF TENNESSEE.

FOR THE

USE OF THE PUBLIC SCHOOLS

AND

OTHER INSTITUTIONS OF LEARNING.

By W. G. McADOO, A.M.

AND

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DEPARTMENT OF PUBLIC INSTRUCTION,

Office of the State Superintendent,

NASHVILLE, TENN., JUNE 23, 1875.

I have carefully read and examined the *Elementary Geology of Tennessee,* by W. G. McAdoo and H. C. White, and find it to be an admirable compilation of the principles and facts contained in the works on that subject, and well adapted to instruction in Common Schools, thus supplying a need long felt, and which was recognized by our public school law as necessary to be provided for.

Respectfully,

LEON. TROUSDALE,

State Superintendent of Public Instruction.

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ELEMENTARY

GEOLOGY OF TENNESSEE.

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INTRODUCTION.

1. In studying the Geology of Tennessee, we study the surface of the State, in relation to the rocks of which it is made.

2. By the word *rock* is meant, not only the solid masses usually known as *rocks*, but also any rock-material whatever, as loose earth, soil, sand, clay and gravel.

3. There are several ways in which we may conduct the study of the rocks in order to obtain from them interesting and valuable information.

(*a.*) In looking out over the surface of the State we observe that it does not exhibit one level plain, but that it comprises elevations and depressions, constituting mountains and valleys, hills and plains, highlands and lowlands, ridges, bluffs and watercourses

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1. What do we study in the Geology of Tennessee? 2. What is a rock? 3. (*a*) What features are presented by the surface of the State?

The *arrangement* of the rocks that gives to the face of the country this changeful shape is a very interesting and important part of the study of them.

(*b.*) If we examine into the character of the rocks themselves, or the materials of which they are made, we find they are not all alike, but differ very much in appearance, and other properties. The study of *the nature and composition* of the different rocks is a very necessary branch of Geology.

(*c.*) We find, also, that they differ very much from each other in the manner in which they have been formed, or built up. Thus, in a railroad cut, we often see rocks in the form of beds, lying one above the other. In other places we find masses of rock, disconnected from all others, without any regular form. Again, there is much difference in the constitution of a bed of thin *slate* and a mass of compact *marble.* The *structure* of the rocks is therefore an important point to be considered in studying them.

(*d.*) Acquainted with the present position, the composition, and the structure of the rocks, we can study them to discover whether the surface of the State has always been as we now find it; or whether it has, in the course of ages past, undergone changes before attaining its present character. In other words, we

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(3. *b.*) Are the rocks all alike? How do they differ? (3. *c.*) Are all rocks formed or built up alike? Explain some of these differences. (3. *d.*) Has the surface of the State been changing or permanent?

can study the *history* in point of time of the *formations* and the *transformations* of the rocks.

(*e*) And knowing the character of these changes, we can search out the causes that gave rise to them, and the nature of the agencies that brought them about.

4. To become acquainted with the Geology of the State, we must study the rocks under these different aspects.

(3. *e.*) What do we learn from studying these changes? (4.) What must we do to understand the Geology of Tennessee?

ELEMENTARY

GEOLOGY OF TENNESSEE.

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CHAPTER I.

A JOURNEY ACROSS THE STATE—ITS PHYSICAL FEATURES.

1. We will now examine the positions and arrangements of the rocks that make up the surface of the State, and which give to it what are called its *physical features*, or its surface-shape and appearance.

2. On referring to the map, we observe that the State of Tennessee, as defined by its boundary lines, has an oblong form, lying between the parallels of latitude 35° and 36° 41′ north, and extending from the Mississippi River directly eastward, to a line lying along a ridge of the Alleghany Mountains, which divides it from North Carolina.

3. Its length, from the Mississippi River to the Mountains, is about three hundred and eighty-five

What is the subject of Chapter I? 1. What shall we first examine into? 2. Describe the geographical position of Tennessee. 3. What are the dimensions of the State?

miles, and its breadth, between the parallels mentioned, is about one hundred and nine miles; it is therefore more than three times as long as it is wide. It comprises an area of about forty-two thousand square miles.

4. Let us travel across it in the direction of its greatest length, and note the leading features of its different portions.

5. Starting from the bank of the Mississippi River, we find ourselves in the midst of a low, flat region, that is a part of the great valley-plain of this river, and known as the "Mississippi Bottom." This plain is from thirty to forty-five miles wide, and through it the Mississippi River runs, dividing it into two portions, one of which (the western) belongs to Arkansas, and the other to Tennessee. The mean elevation of this plain above the sea-level is about two hundred and fifty-five feet, and its average width from the river to its eastern limit is about ten miles.

6. Crossing this low plain in our eastward journey, we are confronted by a line of steep slopes, which rise abruptly to a height of from fifty to one hundred and eighty feet, and which have received the name of the "Mississippi Bluffs." Ascending these, we find that they constitute the western "fringe" or border of a

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4. What direction shall we travel across the State? What shall we note? 5. What is the "Mississippi Bottom"? How many portions does it comprise, and what are they? What is its average width and elevation above the sea-level? 6. Traveling

region of highland which extends eastward to a distance of about eighty-four miles, and which is called the "Plateau of West Tennessee." This is the second prominent physical feature of the State. Its mean height above the sea-level is about four hundred and fifty feet. We find as we traverse it, that it constitutes in reality a gentle *slope*, ascending gradually and continuously, from a level of about three hundred and seventy-five feet at the Bluffs, to that of six hundred and twenty-five feet at its eastern limit. This eastern limit we find to be a line of rough ridges or highlands, elevated to a slight and variable degree above the surface of the slope just described, and overlooking to the east a narrow belt of lowland, or valley, through which runs, in a northerly direction, the Tennessee River.

7. Into this valley we descend very abruptly and by a steep decline, to find the third general physical feature of the State, called the "Western Valley," or the valley of the Tennessee River. This valley has a mean width of only ten or eleven miles, and through it runs the Tennessee River. The average height of this valley above the sea-level is about three hundred and seventy-five feet, and its depth below the high-

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eastwardly, what do we next find? What is the breadth of this highland region? What is it called? What is its elevation above the level of the sea? In what direction does it incline? What are its eastern and western elevations? What constitutes its eastern border? 7. What is the third general physical feature of the State? How broad is the Tennessee River Valley? State its

lands from which we have just descended is two hundred and fifty to three hundred feet.

8. Crossing this valley, we find it bounded on its eastern side also by a line of abrupt and steep highlands, of greater elevation than those on the west, having an average height above the valley of about five hundred feet. These highlands we find to have a very peculiar and interesting form and appearance, constituting, in connection with another portion of the State to be presently described, an important feature. For a distance of about thirty miles we travel across a slightly rolling, but comparatively level, country, of an average height above the sea-level of nine hundred feet.

9. Next we come suddenly upon an abrupt slope, which descends in steep and terrace-like inclines, into a valley or basin, which extends from the foot of the terrace-cliffs by a gradual descent of rolling country to its central and lowest portion, and thence, by a gradual rise of the same character, to its eastern limit; the entire width comprising a distance of about sixty miles. The height above the sea-level of the lowest portion of this basin is about five hundred feet; its average height is probably about six hundred

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height above the sea-level. What is its depth below the highlands? 8. How is this valley bounded on the east? What is said of this new highland feature? What breadth of elevated land do we traverse next? State its elevation above the sea. 9. What do we next come upon? Describe this "basin." How wide is it? State its lowest and its average height above the sea.

feet. The depth of the basin below the highlands before mentioned is about three hundred feet.

10. The eastern limit of this valley or low country is a line of steep cliffs or ridges, similar to those we descended on the west. They rise in the form of successive abrupt terraces to a height of about three hundred and fifty feet above the valley.

Ascending these ridges, we find ourselves upon a great highland plain, in appearance like that to the west of the basin, of comparativly level country, and having an elevation above the sea-level of about nine hundred and fifty feet.

11. The basin we have described is one of the most prominent and important features of the surface of the State, and has been termed the Central Basin.

12. The highlands which adjoin it on both sides have been grouped together for a reason which will be explained hereafter, and are called the "Highlands," or "Highland Rim" of Middle Tennessee.

13. Crossing the width of the eastern highland, a distance of about thirty miles, we come upon a number of high, ragged spurs or ridges, that appear to be thrown out from a great mass of elevated land beyond.

(10.) What constitutes the eastern limit to this valley? How high do these ridges rise above the valley? Ascending these, what do we find? Its appearance? Height? 11. What is this valley or basin termed? What is said of its importance? 12. What are the highlands on the east termed? 13. How broad are these highlands? What do we encounter next?

On examination, these ridges and the indented valleys between them prove to be the western boundary of a vast, elevated region, to which we ascend by a very precipitous and abrupt incline, rising a vertical height of about one thousand feet above the highland plain just left. Arrived at the summit of these steep cliffs, we find ourselves upon an extended plateau having, in general, the character of a level plain, and with an average elevation above the sea-level of two thousand feet. To this very prominent, bold and extensive physical feature of the State, the name "Cumberland Table-land" has been given, although it is known more popularly by the name of the Cumberland "Mountains." The top of the table-land has an average width of about sixty miles, crossing which, to the eastern edge, we descend from our elevated position, along the face of cliffs which are equally precipitous, but not so ragged and uneven as those on the western side.

14. Our descent is into a broad and extensive region of country, constituting the seventh great physical feature of the State, and termed the "Valley of East Tennessee." It is, in fact, a valley, since it lies between regions of mountains or highly elevated land, and furnishes the river beds for draining the

What do they prove to be on examination? What ascent do we next make? What do we find at the summit? State the name and height of this elevation? What is its average width? Mention the character of its eastern slope. 14. Into what do we descend? What great feature does this constitute? Why is it termed a *valley?*

highlands on either side; but it does not partake at all of the character of *lowland*, nor is it in the least similar to the Valley of West Tennessee, before described, met with in the western part of the State.

Crossing this valley, we find ourselves continually encountering, throughout its width, numerous ridges of hilly, and sometimes almost mountainous, country, of varying height and width, with corresponding valleys and gorges between them. Notwithstanding this *rolling* character, the general features of a great valley are preserved sufficiently to make this region as one of the great physical divisions of the State. The average height of the Valley above the sea-level is probably one thousand feet. It therefore has a depth below the top of the Cumberland Table-land of about one thousand feet. Its mean width in an east and west direction is probably fifty miles.

15. Crossing this Valley, we find its eastern boundary to be a ridge of high mountains, rising boldly from the eastern side of the valley, to a great height above it. As we surmount this line of mountains, we find it to consist of a number of ridges, parallel to each other, with numerous outliers and rugged peaks between them. The mean height, above the sea-level, of the first ridge we cross is about two

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How does it differ from the Valley of West Tennessee? Describe the crossing of this valley. What is the mean height of the Valley of East Tennessee? What its average depth below the Cumberland Table-land? Its mean width? 15. What constitutes its eastern boundary? Describe these mountain ridges. State the height of

thousand five hundred feet, being elevated, therefore, above the valley just left, about fifteen hundred feet. Passing eastward to the next principal ridge beyond, we find this to be of the great average elevation of five thousand feet above the sea-level, and along the top of this high and massive ridge runs the State line, which separates Tennessee from North Carolina. In crossing from the valley to this line, we have traveled a mean distance of twelve or fourteen miles. This great mountain region constitutes the eighth and last physical feature of the State, and is known as the "Unaka Chain."

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CHAPTER II.

THE PHYSICAL FEATURES OF THE STATE.

1. We have now traveled entirely across the great length of the State, have observed in our journey each of its great physical features, and learned their names and general character. We shall now inquire

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the first of these ridges. The next. Where do we find the eastern boundary line of Tennessee? From what State does it divide us? Distance from the Valley to the State line?

Chapter II.—Of what does the second chapter treat? 1. State briefly what has been learned in the first chapter. What shall we inquire into next?

more carefully into the detailed and less prominent characteristics of each feature, preparatory to uniting the information we obtain into a general and comprehensive physical survey of the State.

I. *The Mississippi Bottom.*—This name is applied in general to the entire long and narrow river-bottom that lies on both sides of the Mississippi River, from its mouth at the Gulf of Mexico, to a point thirty miles above the mouth of the Ohio River, a total distance of six hundred miles. The width of this strip of lowland is variable throughout its extent, ranging from thirty to eighty miles. A portion of it, on the eastern side of the river, lies, as before described, within the boundaries of Tennessee. The Mississippi River, running through this lowland in a very crooked channel, is continually changing its course, and has perhaps, in times past, occupied at successive periods, every portion of it. The general appearance of this region is that of a flat plain, heavily wooded in many portions, and with numerous bayous, lakes and swamps. The soil where cultivated (as it is in great part, especially along the borders of the river,) is extremely fertile. Only about nine hundred square miles of the area of Tennessee lies within this section.

I. What is the name *Mississippi Bottom* applied to? What is its total length? Breadth? What great river runs through it? What portions of the valley has this river probably occupied? Describe the general appearance of the Mississippi Valley? What area of it lies within Tennessee?

II. *The Plateau of West Tennessee.*—This is a well marked division of the State, and is simple in its general appearance. The surface is gently rolling, and the soil is, for the most part, fertile. It constitutes a high and broad dividing ridge between the valley-bottoms of the Mississippi and Tennessee Rivers. Its average height above the sea-level has been stated. Its highest portion is the south-eastern, where it has an elevation of about six hundred feet. Its lowest is the north-western, where the elevation is about four hundred feet. It therefore has a gentle, but considerable slope to the north-west, and, as a consequence, the rivers which flow over its surface have a course in this direction. This course is generally changed somewhat to the south-west as the rivers strike the "bluffs" which form the western limit of the Plateau, and pass into the Mississippi. Of these rivers, some have long and sluggish courses, with wide, flat bottoms, generally well wooded. The most striking portion of the Plateau, is the line of Bluffs which separate it from the Mississippi Bottom. These bluffs line both sides of the river-bottom throughout its length, are of variable height and boldness, and are sometimes washed at their base by the great river. This occurs

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II. What is the second division called? Describe it. What does it constitute? What are its highest and lowest portions? State the height of these. In what direction does it slope? What is said of the course its rivers flow? Repeat what is said of the number and character of these rivers. What is said of the Bluffs? How often

at four points within the boundaries of Tennessee—Memphis being one point, where the city, situated on the bluff, is one hundred feet above the river.

The Plateau extends beyond the borders of the State for a considerable distance, both north and south.

The area of Tennessee included in this section is about eight thousand eight hundred and fifty square miles.

III. *The Western Valley of the Tennessee River.*—This narrow valley follows the northward course of the Tennessee River, throughout, and beyond the borders of the State. It is remarkable for the broken and varied character of its surface. Immediately along the shores of the river it is flat, and the soil, which is fertile, is generally well cultivated. The highlands, which border the valley on both sides, send out numerous rugged spurs and ridges, which form between them a number of narrow valleys and gorges. Creeks and small rivers run through these valleys, draining this section, and furnishing tributaries to the river Tennessee.

The area of the State included in this division is about twelve hundred square miles.

IV. *The Highland Rim of Middle Tennessee.*—Under

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are these washed by the Mississippi River? What is the height of the bluff above the river at Memphis? Does this Plateau extend beyond the limits of Tennessee? What area in Tennessee does this section include? III. What is the next natural division of the State called? For what remarkable? What does it follow? Describe it. State its area. IV. What is included under the name of the

this name is included, as before stated, the highlands, which lie on both sides of the "Central Basin," extending to the valley of the Tennessee River in the west, and to the base of the Cumberland Table-land east. A comprehensive survey of this section of the State exhibits clearly the reason for classing these highlands together as one general physical feature. The Basin, which is bounded by them on the east and the west, is also bounded by them on the north and the south, as they extend around and meet each other at these points, thus encircling it on all sides. In fact, the Highlands constitute one extensive region of elevated country, stretching from the valley above named, to the table-land in the east; and out of the central portion of this area has been scooped, by natural agencies, the large and interesting valley termed the "Central Basin." The unity and the continuous character of this highland region is well preserved throughout its extent. On every side of the Basin, its general character is the same. This entire region has been compared to a shallow plate with a broad, flat rim. The Highlands are the rim—the Central Basin the shallow portion. The general surface of the Highlands is very flat and uniform, cut very frequently, however, by deep gorges, which form

Highland Rim of Middle Tennessee? Why are these highlands so classed together? Describe the extent of them. How does the Central Basin seem made from them? Is this Highland Rim uniform in its continuity? To what has this Basin and its Rim been compared? Describe the general surface of these Highlands. What is the quality of the soil?

the channels of the streams. The soil is in general fertile, excepting a portion immediately around the Basin, which is characterized by the name of the "Barrens." In elevation, there is a gradual ascent from the Tennessee Valley to the Cumberland Table-land; and this entire region also slopes gently from the south-west, towards the north-west, its lowest portion. The Highlands extend beyond the borders of the State, into Kentucky and Alabama.

The area of Tennessee included by them is about nine thousand three hundred square miles.

V. *The Central Basin.*—This great depression or excavation in the centre of the State is oval in form, having a length of one hundred and twenty miles in a north-east and south-west direction, and a breadth of sixty miles east and west. It is entirely enclosed by the Rim before described, the encircling edge being in great part rough and ragged. Elevated spurs from the Highlands frequently extend into the Basin. A prominent example is Elk Ridge.

There are four outlets from the Basin by narrow valleys or gorges, that cut entirely through the surrounding Rim. These are the two valleys of the

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What are the "barrens"? In what direction does this elevation ascend? Which way does it descend? Which is the lowest portion? Whither do they extend? What is their area of surface? V. What form has the outline of the Central Basin? How is it situated in the body of the State? What is its length? Its breadth? Is the encircling ridge regular, or rough and ragged? Example? How many outlets to this basin? What are they?

Cumberland River, entering and leaving the Basin, the valley of Elk River, and the gorge of Duck River. These rivers drain the Basin, and also, in great part, the surrounding highlands. The tributaries from the latter frequently fall abruptly into the Basin over high cliffs, producing, in many cases, beautiful waterfalls. The surface of the Basin is uniformly rolling, frequently intersected with water-courses of greater or less size. The soil is extremely fertile, and this section constitutes one of the finest divisions of the State.

The area comprised in it is about five thousand four hundred and fifty square miles.

VI. *The Cumberland Table-land.*—This great division is comparatively simple in character. Its eastern border is regular and even, presenting a gracefully curving outline. The western border, however, is very ragged, and projects numerous ridges into the Rim beyond, and many deep indentations into the Table-land itself. These indentations in no place cut entirely through the Table-land. Both borders are capped with sharp, precipitous, and frequently overhanging, masses of rock. The surface of this high region is flat and regular, though it is often crossed by low ridges and shallow valleys, with small streams.

What do these four outlets drain? What is said of waterfalls? How is the surface of the basin described? What is the character of the soil? What the area? VI. Describe the Cumberland Table-land. Do any indentations cut entirely through it? How are the borders capped? Describe the surface of this Table-land.

Numerous outlying ridges and isolated mountains are also associated with, and properly belong to this division of the State. A noted example of the latter is Lookout Mountain. This belt of high land crosses the State in a north-east and south-west direction, and extends beyond its borders in both directions. The soil of the Table-land is less fertile than that of the Central Basin. It embraces within the State an area of five thousand one hundred square miles.

VII. *The Valley of East Tennessee.*—This name is applied to the great trough or depression between the Cumberland Table-land and the Unaka Mountain-chain, through the centre of which the Tennessee River takes its course, in a south-westerly direction, soon after its rise in the mountains of Virginia. Running obliquely across the State, this section consists of a number of alternate elevations and depressions, of greater or less extent, and of diversified appearance. The eastern portion of the Valley is made up of a great number of ridges—large and small—running generally parallel to each other, and in some cases, extending great distances in length. Between, and among these lines of ridges, are numerous small valleys and glens, giving to the general surface an appearance of great diversity. The western

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What other features belong to this division? Give an example. In what direction does this belt cross the State? Is it fertile? State its area. VII. What is the *Valley of East Tennessee?* Of what does this section consist? What is said of the eastern part of this valley? What are found among the lines of ridges? What is the character

side of this great Valley is of a different character, being free from ridges, less abruptly rolling in its approaches to the steep cliffs of the Table-land. The Sequatchie Valley cutting into the Table-land on its eastern side, belongs properly to this division.

Numerous streams channel the surface, following in their course the general trend of the valley, and tributary generally to the Tennessee River. Some of the most important rivers of the State have their channels in this section. The Valley passes beyond the borders of the State on both sides. The area of the State included within it, is about nine thousand two hundred square miles.

VIII. *The Unaka Chain.*—This division comprises the main mountain region of the State. The chain, as already stated, consists of a number (varying from two to four within the limits of Tennessee) of parallel ridges, more or less broken in their extent, but generally continuous, running in a winding course across the eastern border of the State, a distance of two hundred miles, and extending beyond it into Virginia and Georgia. Along the crest of the highest ridge is located the State line, dividing Tennessee from North Carolina. This chain is a portion of the

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of the western side of this valley? To what division does Sequatchie Valley belong? What is said of the streams? To what are they generally tributary? Does this Valley extend beyond Tennessee? What is its area? VIII. What does the Unaka Mountain chain comprise? Describe it. What distance does it extend along the border of Tennessee? Where is the State line located? What does it divide?

Alleghany Mountains. It is decidedly mountainous in character—high, rugged and bold, with broad or narrow valleys between the ridges and spurs, with numerous peaks, lofty summits, roaring torrents and cascades, forming altogether the wildest and grandest natural feature of the State. It is cut in numerous points by deep, rocky gorges, that form the beds of mountain streams, rushing down as tributaries to the rivers in the great Valley below.

It embraces an area of the State, in all about two thousand five hundred square miles.

CHAPTER III.

THE CONSTITUTION OF THE ROCKS.

We proceed now to examine into the constitution and nature of the different rocks, which, grouped together and arranged in a variety of ways, give to the surface of the State its physical features we have just considered. As already stated, we mean by a "rock" any natural aggregation of mineral matter

To what great mountain chain does it belong? Describe it. What is said of its gorges? What is its area?

Chapter III.—What is the subject of Chapter III.? What do we next examine? Define the term "rock." What rocks do we

whatever, whether solidified and massive or not. Although the entire mass of the earth is made up of such rocks, in one form or another, we cannot examine and study them all. We are limited in our inspections and study, at this period of geological knowledge, to those rocks which lie within fifteen or sixteen miles of the surface. With these, we can, in various ways, become well acquainted. The small portion of the earth's mass encircling the earth, like the outer shell of an onion, is called the *crust* of the earth.

Let us, in the first place, study the *constitution* of the rocks, or the materials of which they are made.

An examination of the rocks presents an almost infinite variety in appearance, and very great diversity in other properties, such as hardness, weight, etc. Notwithstanding this great variety, a very few simple mineral substances—either alone, or combined together in different ways—suffice to make up all rocks.

The chief of these substances are—Silica, Alumina, Lime, Magnesia, Potash and Soda. Flint is one form of Silica, and common clay is one form of Alumina.

I. *Silica.* Silica is composed of two elementary substances, joined together in chemical combination—a non-metallic substance rarely obtained in the free

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investigate now? Can we acquaint ourselves with these? What is meant by the crust of the earth? How do rocks vary? Are they composed of few or many simple substances? Mention the names of the principal substances. I. Of what is *Silica* composed?

state, called Silicon and Oxygen gas, the great life-supporting constituent of the atmosphere. It is known by a number of other names, the principal of which are *Quartz* and *Silex*. It occurs in nature in a free, uncombined condition, forming a number of interesting and important minerals and rocks. It also occurs combined with other substances, constituting the important class of minerals called *silicates*. Altogether, it is very abundant, and comprises little less than one-half the earth's entire crust. The most distinguishing property of Silica is its great hardness. It scratches glass with ease, strikes fire with steel, and cannot be cut with a knife. When struck with a hammer, it exhibits brittleness, and breaks into irregular fragments with a glassy appearance. It is unaffected by ordinary acids, and melts only with an intense heat. These refractory properties fit it for the important part it bears in the formation of the rocks. In various forms, and under many names, it is polished, and is worn as gems in jewelry. Free or uncombined Silica is known under a variety of names.

Quartz is a general term, embracing all the varieties which follow. It frequently occurs in crystals of the form shown in the figure.

Which is the life-supporting principle? By what other names is Silica known? How is it found in nature? What proportion of the earth's surface does it constitute? What is its most distinguishing property? Mention its characteristic peculiarities. For what do these properties fit it? In what form does *Quartz* frequently occur? Is it worn as jewelry? What does the illustration

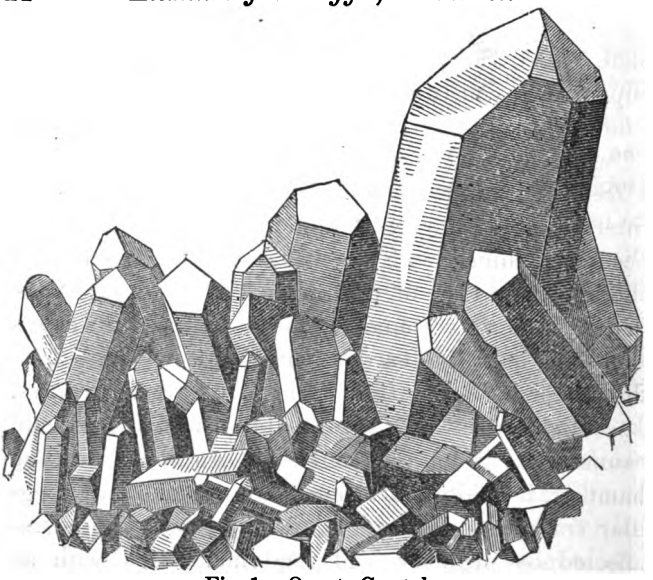

Fig. 1.—Quartz Crystals.

Crystals of great size, though of inferior clearness, are occasionally seen. *Rock Crystal* is, properly, the clear crystalline quartz, but the name is usually extended to any clear, white, transparent variety.

Rose or *Pink Quartz* is a rose-red variety of clear quartz, rarely found as crystals, but usually massive. Amethyst is clear quartz, with a beautiful purple color, given it by the Oxide of Manganese, which it contains.

Milky Quartz has a milk-white appearance, and is usually found opaque and massive.

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show? What is Rock Crystal? To what is the name usually extended? What is Rose, or Pink Quartz? Amethyst? Whence its purple color? What is Milky Quartz? What is the appearance

Smoky Quartz has a dark, brown, smoky tint. It is sometimes black and opaque.

Granular Quartz consists of small grains of quartz, united to form a massive rock. It has a texture like loaf-sugar, and frequently crumbles easily into sand.

Chalcedony is a massive quartz with a waxy lustre. It is generally white or brown in color. *Carnelian* is a bright red; *Sard* a brownish red, and *Chrysoprase* an apple-green variety. *Agate* is a kind of chalcedony, in which different colors are arranged in parallel bands. Different names are given to agates, according to the figures which it is fancied are marked out by the colored bands. Thus we have *fortification*, *ribbon*, and *moss* agates. These bands are seen in cutting *across* the stone; they are in fact, successive layers of quartz one upon the other. When an opaque alternates with a transparent layer, the stone is an *onyx*. Real *cameos* are cut from the onyx.

Jasper is a dull, massive variety of quartz, of various shades of color. When the colors are arranged in bands, it is called *ribbon* Jasper. When it is a deep green, with red spots, it is called *blood-stone*, which is often set in finger-rings.

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of Smoky Quartz? Of what does Granular Quartz consist? Chalcedony? What color? What is the appearance of Carnelian? Sard? Chrysoprase? What are Agates? What different names are given to them, and why? How are the bands made? When is an Agate termed an Onyx? From what are real Cameos? What is Jasper? When is it termed *Ribbon* Jasper? When *Blood Stone?*

Sand, Pebbles, Gravel, etc., are forms of quartz, usually associated with other materials. Flint, Hornstone, and Buhr-stone are also forms of compact quartz, usually of fine texture and great hardness.

Opal is a combination of Silica and water. It is softer than quartz, is usually white, and forms a beautiful gem, exhibiting an internal play of colors.

2. *Alumina.—Alumina* is a compound of a metal, *Aluminium*, and *oxygen*. It occurs free and uncombined only in a few forms, and these in very limited quantities. *Sapphire* is a clear, blue, crystallized variety, constituting a rare and beautiful gem, greatly prized by jewelers. *Corundum* is a massive black, opaque variety, and *Emery* is a coarsely granular form. Alumina is even harder than quartz, and can only be scratched by the diamond.

Besides this rare occurrence in a free state, alumina is a constituent of a number of important minerals.

3. *Lime.—Lime* is composed of a metal, *Calcium*, and *Oxygen*, chemically united. It does not occur in nature in a free state, but is prepared artificially, and is well known as "*quick lime.*" There are two compounds of Lime which form groups of important and interesting minerals.

Of what are sand, pebbles and gravel composed? What are flint, hornstone and buhr-stone? What is Opal? Describe it. What is Alumina? How does it occur? What is Sapphire? Corundum? Emery? How hard is Alumina? Does it combine with other minerals? Of what is Lime composed? Is it found in a natural state? How many important groups of compounds has it? What

1. *Calcium Carbonate,* or Carbonate of Lime, is a compound of lime and carbonic acid. This is a soft mineral, easily cut with a knife, and readily recognized by *effervescing* (giving off carbonic acid gas) when treated with vinegar or a weak acid. It is almost insoluble in pure water, but is somewhat soluble in water containing carbonic acid gas. Rain water is a solvent for it in a slight degree, as this contains a small amount of carbonic acid, washed out of the air, in its descent to the earth. It occurs in a variety of forms, of which the following are the most important:

Calc Spar, or Calcite, is a clear, transparent, crystallized variety, in the form of a rhombohedron. Quantities of it are found in Iceland, hence it is sometimes termed *Iceland Spar.*

Dog-tooth Spar and *Nail-head Spar* are names applied to certain crystallized varieties whose forms suggest the titles. *Limestone* is a name applied sometimes to all varieties of Calcium carbonate, but more generally to the massive forms only. It occurs frequently in large masses, constituting whole beds of rocks of various colors, extending over great regions of country. It abounds throughout large portions of Tennessee, and constitutes the material of which the Capitol at Nashville is constructed.

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is the first? Describe Carbonate of Lime. How easily recognized? Is it soluble in water? How soluble? What does rain-water contain? Describe *Calcite.* Where are quantities of it found? What are Dog-tooth spar and Nail-head spar? What is Limestone? Where is it found? What noted public building is constructed of

Marble is crystallized limestone, in a compact form. There are many varieties, of various colors and names. It will receive a high polish, and is an important building material.

Oolite and *Pisolite* are limestones containing numerous small, rounded grains.

Calcareous Tufa is a deposition of calcium carbonate, from water holding limestone in solution. In limestone countries the rain-water frequently excavates, by its solvent action, great cavities in the rocks. These are called "limestone caves" or caverns, and are sometimes of great extent and beauty. Water charged with limestone, trickling through the roof of such a cave, deposits its limestone and forms masses, called *stalactites*, pendent from the roof. A portion falling upon the floor of the cave deposits its limestone there, and in time, masses called *stalagmites*, are built up from the floor.

Chalk is a porous, crumbling variety of limestone. It sometimes occurs in large deposits. Its uses on the black-board are known to every student.

Marl is a mixture of limestone and clay. It generally occurs in great beds, is loose and uncompact, and contains numberless small shells. It is employed to fertilize lands.

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it? What is Marble? Are there many kinds? For what is it chiefly employed? What are Oolite and Pisolite? What is Calcareous Tufa? How are limestone caverns formed? What are stalactites? Stalagmites? What is Chalk? Marl? How do

Magnesian Limestone, or *Dolomite*, contains magnesia. It is somewhat harder than ordinary limestone, and does not effervesce with acids unless heat be applied. It sometimes occurs in natural beds of great extent.

Calcium Carbonate is the most important constituent of the shells of marine animals. These frequently furnish it, as we shall learn in another place—in the formation of the rocks.

2. *Calcium Sulphate*, or Sulphate of Lime, is a compound of lime and *sulphuric acid*. As found in nature, it also contains, usually, *water* in chemical combination. This mineral is softer than calcium carbonate. It can be scratched with the finger-nail, and easily cut with a knife. It does not effervesce with acids.

It occurs crystallized in a number of forms, prominent among which are *satin spar*, (in fibrous masses with the lustre of satin,) *Selenite*, (in scales and plates, with an appearance like the *sheen* of the moon,) and *alabaster*, a snowy-white solid. In a massive form (which is its principal mode of occurrence,) it is known as *Gypsum*. It is sometimes called *land-plaster*, and when burned, "*plaster of Paris.*"

Gypsum occurs naturally in extensive beds, constituting important rocks.

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these occur? What is Dolomite? How different from Limestone? How does it occur? What is Calcium Carbonate? What is said of it? What is Calcium Sulphate? How composed? What qualities does it exhibit? How does it occur? What is Satin Spar? Selenite? Alabaster? Gypsum? What is Land-Plaster? Plaster of Paris? How does Gypsum occur in nature? What are

3. *Magnesia, Potash* and *Soda* are the *oxides* of the metals Magnesium, Potassium and Sodium, respectively. Magnesia occurs to a very small extent in nature in a free, uncombined form. Potash and Soda do not occur at all in this condition. They are very important in their different compounds.

Compounds of Silica and other substances.—Silica, besides its importance and abundance in a free state, as already described, unites with the substances above named, and with others of less importance, forming what are called *Silicates.*

The Silicates are a highly important class of minerals. We mention a few of the chief ones.

1. *Feldspar* is a silicate of alumina essentially, with other substances, which are changeable. *Orthoclase* (common-feldspar, potash-feldspar,) contains potash; *Albite* (soda-feldspar,) contains soda, and *Labradorite* (lime-feldspar,) contains lime. All these varieties agree in being somewhat softer than quartz, of light color usually, and breaking rather readily into well-defined crystals.

Common Clay is a silicate of alumina, formed by the decomposition of feldspar, the other substances being washed away. It is usually stained of various colors by the oxide of iron associated with it.

Magnesia, Potash and Soda? How do they occur? With what does Silica unite? What are its compounds termed? Are they important? What is Feldspar? Orthoclase? Albite? How do these differ from Quartz? What is common clay? How usually

2. *Mica* is a mineral readily distinguished by its bright, glistening appearance, and great lustre. It can be easily split into very thin, elastic plates, and is frequently seen in the form of small shining particles. It is well known under the name of "isinglass." Mica is a silicate of alumina and potash, containing also a small quantity of iron.

3. *Hornblende* is a tough mineral, nearly as hard as feldspar, of black or dark color generally, and frequently found in the form of long, needle-like crystals. It is a silicate of magnesia and lime, usually containing, in addition, small proportions of alumina, iron, and other substances.

Fig. 2.—Hornblende Crystals in Quartz.

4. *Pyroxene* is very like hornblende, both in composition and appearance, occurring, however, frequently light colored, and differing from hornblende in the form of its crystals.

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stained? What is Mica? Its appearance? Qualities? What is Isinglass? Of what does Mica consist? How is Hornblende found? Properties? What does the illustration show? What does Pyroxene resemble? Appearance? How different from Hornblende?

Asbestos is a name applied to a variety both of hornblende, and pyroxene, occurring in *fibrous* form, resembling the texture of wood.

5. *Talc* is the softest mineral known, and can be easily scratched by the finger-nail. It is readily distinguished by its softness, and its greasy, soapy feel. It presents usually a light green color. and separates into thin, flexible layers. Talc is a silicate of magnesia, containing, in addition, water and a little iron.

Soapstone, or *Steatite,* is a massive, crystalline variety of talc.

Serpentine is a species of talc, of compact texture and massive form. It has frequently a mottled appearance, resembling the skin of a serpent.

Chlorite is a dark green mineral, resembling talc in composition, but compact, and much less greasy in feel.

6. *Tourmaline* occurs in long prisms, commonly of a black color, well defined in form and highly polished. It is a silicate of alumina, with the addition, usually, of lime or magnesia, iron and boracic acid.

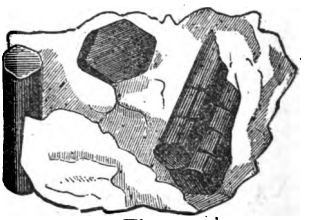

Fig. 3.
Tourmaline Crystals in Quartz.

To what is the term Asbestos applied? Talc? How can it be distinguished? What is its color? Of what is Talc composed? What is Steatite? Serpentine? What appearance does Serpentine present? Describe Chlorite? How does Tourmaline occur? What is Tourmaline composed of? What does the illustration show?

It must not be supposed that the minerals we have thus described, form of themselves, individually, the great masses of rock we find spread out over the surface of the earth. On the contrary, the rocks are *aggregations* of these minerals, differing in kind and proportion; and these aggregations constitute the true rocks. To these different rocks are applied special names, with which we must now become familiar.

1. *Sandstone* is common sand, cemented into a hardened mass by common clay. Sandstones are *siliceous*, or argillaceous, (clayey,) according as the sand or clay is present in greater amount.

2. *Conglomerate* is gravel cemented into a rock by clay, which may be siliceous, calcareous, or feruginous, (containing much iron,) and thus give a distinctive name to the mass. If the gravel pebbles are rounded, it is a "*pudding stone*," and if angular, a "*breccia*."

3. *Shale* is common clay, hardened and compressed into a compact rock, easily breaking into thin, fragile layers like roofing slate.

4. *Trap Rocks* are very hard, dark colored, dull looking rocks, generally very massive in character. There are four principal varieties, viz:

Do these minerals form large masses on the earth's surface? Of what are the rocks formed? Have these aggregated rocks special names? What is Sandstone? What two kinds are there? What is conglomerate? How differently composed? When called Pudding Stone? When Breccia? What is Shale? What are Trap Rocks? How many kinds are there?

(*a*) *Basalt* (also called *Dolerite,*) composed chiefly of augite and feldspar.

(*b*) *Dionite,* composed of hornblende and feldspar.

(*c*) *Porphyry,* composed almost entirely of feldspar, with distinct crystals of the same scattered through it. It is frequently of light colors, such as red and purple. Any trap rock in which feldspar is disseminated in the form of distinct crystals, is said to be *porphyritic.*

Fig. 4.—Porphyry.

(*d*) *Amygdaloid* is a trap rock containing rounded cavities, frequently filled with quartz and other minerals.

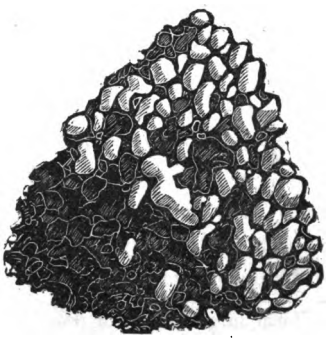

Fig. 5.—Lava (Scoria), in part turned into an Amygdaloid.

What the first, and how composed? The second, and how composed? The third? What appearance does it present? What are porphyritic rocks? What is Amygdaloid? What do the illus-

5. *Granite* is a hard, compact, granular rock, composed of quartz, feldspar and mica. It has usually a greyish color. The three minerals may be easily distinguished in the rock by their individual peculiarities. There are a number of varieties of granite, differing in color, hardness, compactness, and other properties.

6. *Gneiss* has the same composition as granite, but, differs from it in not being granular, but laid out in beds.

7. *Mica Schist* is a gneiss rock, in which *mica* is the chief constituent.

8. *Syenite* is a granite-like rock, consisting of quartz, feldspar and hornblende.

9. *Quartzite* is a harsh, gritty rock, formed by the fusion of quartz-sand into a compact form.

10. *Volcanic rocks* are those produced by the overflow of volcanoes. The principal are, *trachyte, lava, pumice* and *obsidian.* They consist chiefly of mixtures of the various mineral silicates described above.

CLASSIFICATION OF THE ROCKS.

The rocks we have just described present differences in appearance, which are not caused by the differences in mineral composition, but evidently by the different

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trations show? How is Granite composed? Describe it. Is all Granite exactly alike? How does Gneiss differ from Granite? What is Mica Schist? What is Syenite? Quartzite? What are Volcanic rocks? The principal kinds? Of what do they chiefly consist? What differences do the rocks just considered present? What other differences exist in them? On what is our next classi-

ways in which the rocks themselves were formed. We have, therefore, a *classification* of the rocks, based upon the modes in which, it is supposed, they were formed.

1°. *Igneous rocks* are those which appear to have been at one time melted by great heat, and to have obtained their present form by cooling. *Trap rocks* and *volcanic rocks* are included under this head.

2°. *Sedimentary rocks* are those which appear to have been laid out in extensive beds by the act of deposition from water. *Sandstones, Conglomerates, Shales* and *Limestones* are included under this head.

3°. *Metamorphic rocks* are those which appear to have been at one time deposited as sedimentary rocks, but afterwards changed in character (usually crystallized or granulated) by the action of heat or some other powerful natural agency. Such rocks are the *granites, gneiss, mica schist, syenite, quartzite* and *marble.*

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fication of rocks based? What are Igneous Rocks? What do these include? What are Metamorphic Rocks? What do they include?

CHAPTER IV.

STRUCTURE OF THE ROCKS.

§ 1. HAVING studied the chemical composition, and mineral constitution of the rocks, let us now examine into their conditions of *structure.* We may here premise, what we shall learn hereafter, that the present form and structure of the rocks have been brought about mainly by the action of two powerful agents—fire and water. It will appear that the whole earth was, at one time, in the condition of a vast mass of melted, highly-heated rock, which, by loss of heat, or cooling, became solid, and formed the massive shell, surrounding the earth as its crust. The great bodies of water, called the *seas,* were afterwards formed, and spread over a great part of the cooled surface, leaving a small portion as *dry land.* The ceaseless action of the seas, beating upon the dry land, crumbled and broke down great parts of it into the condition of fine powder, which, carried out into the seas by the waves, was deposited at their bottoms, and pressed by the great weight of the waters into immense beds, or *strata.*

What is the subject of Chapter IV.? What has been studied? What agents produced the present form and structure of the rocks? What form was the earth in at first? By what process was the solid crust formed? When were the seas formed? What effect had the seas on the land? What are *strata?* Into what two classes are

§ 2. These were the principal conditions under which the rocks were formed, and they are, therefore, divided into two classes, according to their structure, viz: the *stratified,* or those which occur in beds or layers, formed by deposition from water, and the *unstratified,* or those which do not occur in beds, and were formed by the cooling of melted rocks.

Fig. 6.—Stratified Rocks.

§ 3. Had these processes of cooling and deposition gone on without interruption, the surface of the earth would now present small bodies of dry land, consisting of unstratified rocks, and large bodies of water as the original seas. Or, in case some of these latter had become filled up, or removed by some cause from their original positions, there would be found, in their stead, the last deposits of stratified rocks which they had formed. Under such conditions, our study of the rocks would be limited to the surface, and to such depths as could be penetrated by artificial means, which would probably be not more than half a mile.

§ 4. But the processes mentioned did not go on

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the rocks divided? How were the Stratified Rocks formed? The Unstratified? What does the illustration show? Had the cooling and deposition gone on quietly, what would have resulted? If the seas had been filled up, what then? How would the study of the rocks have been limited then? Did they go on quietly? To what

quietly, but were, on the contrary, subjected to powerful disturbances. The great heat which still existed in the interior of the earth, and kept the uncooled masses of rock in a melted condition, broke up, from time to time, the outer crust, and ejected great masses of these rocks, which became, on cooling, parts of the unstratified surface. The stratified deposits already formed were broken up and dislocated by these agencies, and their edges, in many cases, turned up, to form thereafter parts of the earth's surface. The seas were at the same time removed from their positions, and transferred to other localities, to perform their work of decomposition and deposition. It therefore happens that the exterior surface of the earth presents, at this time, a confused and intricate appearance, being made up, not only of unstratified rocks, and those which, being stratified, remain in the original horizontal position as they were first formed, but also of the edges of the dislocated strata, turned up in the manner described. It is by means of the information furnished us by these upturned edges, that we are enabled to study the rocks, to what would be a depth of about fifteen miles, if the strata were placed horizontally one upon the other.

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subjected? In what manner did disturbances occur? What happened to the stratified deposits already formed? What happened to the seas? What is presented therefrom? How is the earth's surface made up? To what depths are we thus enabled to study the rocks?

§ 5. The entire cooled mass of rocks constituting the crust of the earth is, at this time, probably about fifty miles in thickness.

The exterior surface is composed largely of stratified rocks, these constituting about nine tenths of the surface. The interior, however, consists almost entirely of the unstratified. The stratified rocks are by far the most important in the study of Geology.

§ 6. It will now be necessary for us to become acquainted with the scientific definition of certain terms concerning the structure of the rocks, which will be frequently used in our subsequent study.

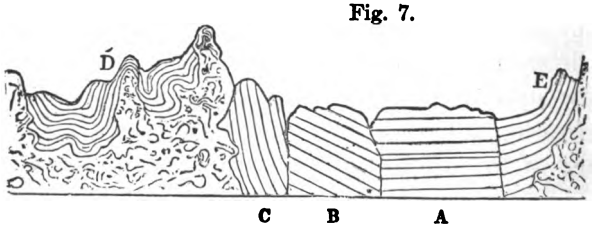
I. Of Stratified Rocks—

A *stratum* includes one or more layers of any particular kind of rock.

A *formation* is composed of several strata which were deposited in the same period.

A *group* is a part of a formation, consisting of strata related to each other.

Fig. 7.



How deep is the cooled crust of the earth, probably? What proportion of the surface is covered by stratified rocks? Of what does the interior consist? Which rocks are the most important in studying Geology? What must we next become acquainted with? What is a *Stratum?* A *Formation?* A *Group?* Explain the Figure on this page.

In Fig. 7, the strata at A are *horizontal*, those at B *inclined*, at C *vertical*, at D *contorted*, and at E *tilted up*.

The angle which inclined strata make with the horizon is called the *dip*. The line of direction at right angles to the dip is called the *strike*.

Strata dipping in opposite directions, as at *a*, Fig. 8, are called *anticlinal;* when dipping towards each other, as at *s*, *synclinal;* strata coming to the surface, as at *c*, are called an *outcrop;* strata arranged regularly above each other, as at *o*, are said to be *conformable;* those not, as at *x*, are *unconformable*.

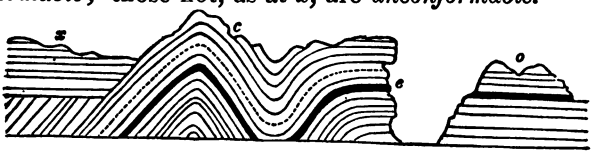


Fig 8.

Massive strata are those of compact form; *shaly* strata break easily into thin slabs, like roofing slate, which are generally fragile; *laminated* strata break readily into slabs like flagging-stone.

In addition to these usual forms of strata, there are those said to be *irregularly bedded*, or to present *diverse stratification*. Such are the strata which appear to have been formed along the beach of some sea, and subjected to the action of the tide in ebbing and flowing, to the drifting of sand, etc. See Fig. 9.

What are *anticlinal* strata? When are they termed *synclinal?* What are termed an *outcrop?* When are strata *conformable?* When *unconformable?* What are *Massive* strata? *Shaly? Laminated?* What is meant by *irregularly bedded* strata? What is *diverse* stratification?

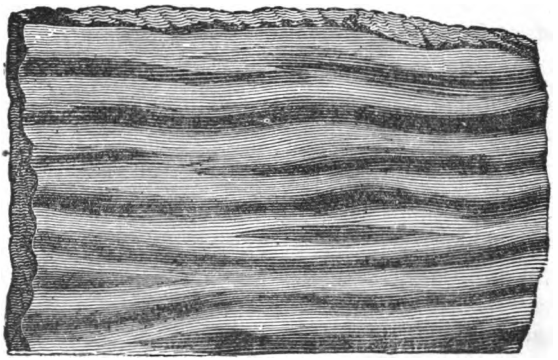


Fig. 9.—Ripple Marks.

Strata frequently exhibit upon their surfaces certain *markings*, such as ripple marks, wave marks, mud cracks, and the prints of rain drops. See Fig. 10.

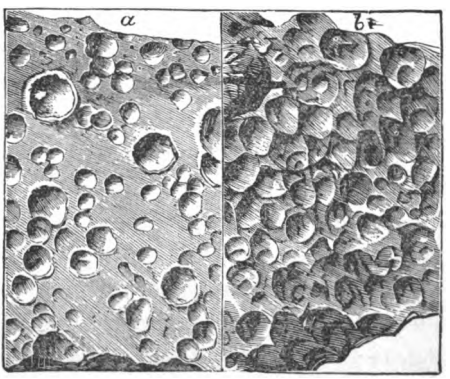


Fig. 10.—*a.* Modern impressions of rain-drops.
b. Carboniferous impressions of rain-drops.

How were they formed? Explain the figure illustrating ripple marks. Explain the illustrations of rain drops. What is a *fault*?

It sometimes happens that cracks or seams (generally nearly vertical) traverse strata in such a way that they are dislocated on either side, and their continuity is destroyed. Such dislocation is termed a *fault.*

When these seams are numerous, and run parallel to each other, accompanied at the same time by another system of seams at right angles to the first, it gives rise to what is called a *jointed structure.*

Strata are frequently folded upon each other in such a way as to present great difficulty in the study of them. The tops of the folds have sometimes been entirely cut off, or *denuded,* by the action of the water, so as to give the appearance of a double set of strata to what is in fact but one. Fig. 11 represents a regular, and a denuded fold.

Fig. 11.—A decapitated fold.

In addition to the various forms of strata described above, there occur certain peculiar forms of rocks, produced by the action of water, known as *concretions.* These are composed generally of *clayey,* but frequently of other, materials, and are aggregations of the matter around a centre or *nucleus.* They are usually

What is *jointed structure?* Are strata folded on each other? Explain how the folds are sometimes cut off. What does the accompanying figure represent? What other strata exist? What are concretions? What form have they?

more or less globular in form, but their shape is often so modified as to present very curious appearances. When the nucleus consists of a cavity lined with little crystals of quartz or other mineral matter, the concretion is termed a *geode.*

2. Of Unstratified Rocks—

The unstratified rocks are usually found in masses devoid of any regular shape, *underlying, overlying,* and sometimes *penetrating,* the stratified rocks.

It frequently happened that in the cooling of the melted rocks, or in the drying of those deposited from water, cracks or fissures were formed in them. These fissures were subsequently filled with mineral matter, giving rise to what are called *veins* and *dikes.*

Veins differ very much in their extent, from small seams extending only through one formation, to immense fissures, penetrating probably through the entire thickness of the earth's crust. They usually contain a number of mineral substances, such as quartz, serpentine, etc., which are generally crystallized. They frequently contain valuable deposits of metallic ores. Numerous small veins often ramify from the main ones.

Dikes are formed usually of larger fissures than veins; they are not connected with smaller fissures;

What is a *geode?* How are the unstratified rocks usually found? How were cracks or fissures formed in them? What are *veins* or *dikes?* What is said of veins? What do they usually contain? What valuable contents? Have these veins smaller branches? Wherein do *dikes* differ from *veins?* What do they always contain?

are more uniform in dimensions throughout their length, and contain but one kind of rock, which is always of igneous origin, such as the trap rocks.

Dikes were probably always formed by ejections of igneous matter from the interior of the earth. Veins were probably sometimes so formed, and sometimes by agencies connected with the rocks through which they penetrate.

We have now studied the composition, the constitution, and the structure of the rocks, which make up the crust of the earth. This department of Geology is called *Lithological* Geology, or the study of the rocks proper.

CHAPTER V.

MINERAL RESOURCES, AND INDUSTRIAL RELATIONS.

1. LET us next make a brief practical review of the mineral resources of the State, and note their value and industrial relations, as giving rise to or encouraging and stimulating mining, manufacturing, commercial, agricultural, and other great industries.

2. Inasmuch as reference will sometimes be made

How were they probably formed? How, veins? What has now been studied? What is this department of Geology called?

What is proposed in chapter V? How many Civil or Political

to the civil or political divisions of the State, we explain what these are. They do not coincide with the geological divisions referred to in the preceding pages, but are three in number.

3. *East Tennessee,* of which Knoxville is the geographical center, commencing at the eastward limit of the State and traveling westward, is that portion extending from the North Carolina line to an approximate line, dividing equally, from north-east to south-west, the region described as the Cumberland Table-land. East Tennessee, therefore, contains the eastern half of the sixth geological division, and all of the seventh and eighth divisions. Area of this division, 13,700 square miles; population, 330,000, of whom 37,000 are colored.

4. This great division embraces the following thirty-three counties: Anderson, Bledsoe, Blount, Bradley, Campbell, Carter, Claiborne, Cocke, Grainger, Greene, Hamblen, Hamilton, Hancock, Hawkins, James, Jefferson, Johnson, Knox, Loudon, McMinn, Marion, Meigs, Monroe, Morgan, Polk, Rhea, Roane, Scott, Sequatchie, Sevier, Sullivan, Union, and Washington.

5. East Tennessee is noted for its great variety of agricultural and mineral productions. As soils are, in great part, results of disintegration of rocks, the

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Divisions of the State are there? Are they the same as the Geological Divisions? What is the Central City of East Tennessee? What does East Tennessee embrace? What Geological Divisions? Its area? Population? How many Counties? Name them. For what is East Tennessee noted? Whence arises the variety of soils

great variety of the latter would effect equal variety of soils. For the most part, these soils are eminently productive. They yield to the faithful laborer good reward in fruits of agriculture; and the mineral products of East Tennessee excel in value those of the other divisions, and vie, in this respect, with the most favored countries on the globe.

6. The second great civil division of the State is *Middle Tennessee*, which extends from the western limit of East Tennessee, westwardly, to the Tennessee River in its northward passage across the State. Of this division Nashville, the capital of the State, is the approximate geographical center. It embraces the eastern half of the third geological division, all of the fourth and fifth divisions, and the western half of the sixth. Area of this division, 18,000 square miles; population, 562,000, of which 157,000 are colored.

7. This great division embraces the following forty counties: Bedford, Cannon, Cheatham, Clay, Coffee, Cumberland, Davidson, Dickson, DeKalb, Fentress, Franklin, Giles, Grundy, Hickman, Houston, Humphreys, Jackson, Lawrence, Lewis, Lincoln, Macon, Marshall, Maury, Montgomery, Moore, Overton, Perry, Putnam, Robertson, Rutherford, Smith, Stewart, Sum-

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in this region? What is said of their productiveness? How do its mineral products vie with those of other countries? What does Middle Tennessee embrace? What City in its geographical centre? Of what is Nashville the Capital? What geological divisions does Middle Tennessee embrace? What is the area of this Division?

ner, Trousdale, Van Buren, Warren, Wayne, Williamson, and Wilson.

8. Middle Tennessee is distinguished by its great agricultural productiveness, excelling in this respect either of the other divisions, and in mineral wealth it is but little inferior to East Tennessee. The part geologically described as the Central Basin, is especially noted for its richness in products of the farm and the plantation. Its extensive coal-field on the Cumberland Table-land is counterbalanced by an area of iron ore on its opposite border, the latter embracing about four thousand square miles.

9. The remaining great division is *West Tennessee*, which includes the area lying between the Tennessee River on the east, and the Mississippi River on the west. The city of Jackson is its approximate geographical center. It embraces all of the first and second of our geological divisions, and about half of the third. The area of this division is about 10,700 square miles; population, 368,000, of which 128,000 are colored.

10. West Tennessee embraces twenty counties, named as follows: Benton, Carroll, Crockett, Decatur, Dyer,

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Population? How many Counties of Middle Tennessee? Name them. For what is this Division distinguished? What is said of the Central Basin? Has it a Coal field? Where? Iron ore? Where? What is the area of its iron deposits? What is included in West Tennessee? What City in its Geographical centre? What geological Divisions are embraced in it? What is its area? Population? How many Counties in West Tennessee? Name them.

Fayette, Gibson, Hardeman, Hardin, Haywood, Henderson, Henry, Lake, Lauderdale, Madison, McNairy, Obion, Shelby, Tipton, and Weakley.

11. West Tennessee is noted for its agricultural productions, the Mississippi Bottoms, which it includes, being particularly and inexhaustibly fertile; and for its commercial facilities, arising from river navigation and extensive railway lines. Much of the other portions are highly productive. It excels Middle Tennessee, but not East Tennessee, in the variety of its soils. In mineral resources, it is inferior to the other divisions of the State. Small but valuable deposits of iron ore are found, and some other minerals also, which will be mentioned in the proper place.

MINERALS.

12. Commencing at the eastern limit of the State, and traveling westward in this examination, we consider first that metal which is of the highest importance of all to the uses of man, viz:

Iron. Two great bands or "belts" of iron ore extend through East Tennessee, near to and parallel with its ranges of mountains, and are designated and distinguished by the names, *The Eastern Belt* and *The Dyestone Belt.*

For what is West Tennessee noted? How does it compare with the other Divisions in variety of soils? How in mineral resources? What metal is of highest importance to man? Where and in how many places are the ores of iron found in East Tennessee? What are the iron "Belts" termed? What is said of the iron-ore of the

13. A third occupies the entire Cumberland Table-land, but the ore is of less value than those mentioned, and will not be considered further. It is an argillaceous carbonate of iron, and is popularly called *clay iron-stone.*

14. The Eastern Belt lies mainly at and near the base of the Unaka Mountains, and extends entirely across and beyond the eastern border of the State, in an irregularly shaped band, reaching from the Virginia border to Georgia. The iron ore chiefly found in this belt is the *limonite,* or brown hematite, and it exists in various forms. Sometimes it is a yellow powder, when it is known as yellow-ochre; again, it appears as a porous, spongy mass, when it is termed honey-comb ore, and often it assumes the form of balls, or irregular masses, somewhat resembling *slag.* In its purest form, it yields about sixty per cent. of metal to the manufacturer. In a number of the localities of the Eastern Belt, other varieties of iron ore, classed with the red and the brown hematites, are also found.

15. In all of the counties of the Eastern Belt, iron manufactories are in operation. Iron ores are found in the counties of Johnson, Carter, Greene, Washington, Cocke, Sevier, Blount, Monroe, McMinn, and Polk.

Cumberland Table Land? Where does the Eastern Belt lie? What kind of iron ore is here found? Mention some of its varieties. What is the average yield of these ores in metallic iron? Name the Counties of this Eastern Belt. Are iron manufactories in operation in this Belt? In what Counties is the iron ore of the Dye-

16. *The Dyestone Belt*, is the name by which the other iron region of East Tennessee is designated. It embraces, in whole or in part, the following counties: Anderson, Bledsoe, Bradley, Campbell, Claiborne, Grainger, Hamilton, Hancock, James, Marion, Meigs, Rhea, Roane, Sequatchie, and Union.

17. The predominant ore of this belt is a brown or reddish iron-rock, lying in beds or strata, called in many places *dye-stone*. This may be readily known by its weight, brown or reddish appearance, and by the stain which the softer varieties are apt to leave on the fingers when handling it. It is, also, an oxide of the metal, and yields a large per cent. of pure iron when subjected to the process of manufacture.

18. One or more layers or beds of this valuable ore lie along the south-eastern base of the Cumberland Mountains throughout the State of Tennessee, and other beds of the same exist in the parallel ridges within ten or twelve miles of this range; also, in the Valley of Elk Fork, in Campbell County, (a deep depression of the Cumberland Table-land) and in Sequatchie Valley, in a similar depression, are other extensive outcrops of the same.

19. The ores of the Dyestone Belt have also attracted manufacturers, and a number of furnaces are in operation, converting them into metallic iron.

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stone Belt found? What is the predominant ore of this Belt? What is it popularly termed, and how may it be known? What is its chemical character? Where do the beds of this ore lie? Do

Proceeding westwardly, we find an iron belt on the eastern side of the Central Basin, at the base of the Cumberland Table-land, occupying more or less of the counties of Warren, White, Putnam, Overton, and Van Buren, a portion of the "Highland Rim" heretofore described; and to the west of the Central Basin, at the western portion of this "Rim," we find an important belt of iron ore, nearly fifty miles wide, reaching across the entire State from north to south, embracing the following counties, in whole or in part, and termed the *Western Iron Belt*:

20. Stewart, Houston, Montgomery, Dickson, Benton, Humphreys, Hickman, Decatur, Perry, Lewis, Hardin, Wayne, and Lawrence. A line drawn from Clarksville to Florence, Alabama, would pass through the center of this iron belt. The ore of this region is chiefly the kind known as brown hematite. Of these counties, Benton and Decatur lie wholly, and Hardin partly, west of the Tennessee River, in the great division of the State known as West Tennessee; the others, in Middle Tennessee.

21. *Copper.* Copper ores, of remunerative quality to the miner, have been found in Polk County, and in

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manufactures of iron exist in the Dyestone Belt? In what counties at the Western base of the Cumberland Table-Land is iron ore found? What important Iron Belt is found West of the Central Basin? What is it termed? Describe its width and location. What Counties are embraced in it? Between what points would a line pass through its centre? What kind of ore is here found? In what Counties of Middle Tennessee does this Belt lie? In what of West Tennessee? Where are Copper ores found? What is the

no other portion of the State. The locality yielding copper embraces an area of about forty square miles, and comprises a basin about two thousand feet above the level of the sea. It is situated near the Unaka Mountain-range, constituting the south-eastern boundary of Tennessee.

22. An active manufacturing centre, called Ducktown, has grown up at these mines, where metallic copper is produced from the *copper pyrites*, the predominant form of the ore at that place, and also from the red and the black oxides of that metal. To obtain these ores, shafts are sunk to considerable distances in the earth. There are two companies now engaged in the production of copper, the *Union Consolidated Company* and the *Burra-Burra Company*. These companies send forth to the uses of man more than two millions of pounds of copper annually.

23. *Lead.*—Mines of lead have been discovered in several localities in East Tennessee, the ore existing always in the form of the *sulphuret* of lead, or *galena*. Of these, the most promising is the Caldwell Mine, in Union County, where an abundant deposit is known to exist. The Hambright Lead Mine, in Bradley County, was in active operation during the recent

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area of the copper-yielding territory? Its altitude? Where is it situated? Name its manufacturing centre. What is the predominant copper ore termed? What other ores are used? How are these ores obtained? Name the companies engaged in producing Copper? What amount of Copper do they produce? Where is Lead found? In what form? What mine is the most promising?

war, and yielded largely. There are also mines of lead in Bumpass Cove, in Washington County, and the Carter and Montgomery Mines in Monroe County. Only one mine in this region is now in active operation. Lead has also been found in Middle Tennessee, but not in sufficient quantity to justify mining operations.

24. *Zinc.* Ores of Zinc are found in the counties of Union, Claiborne and Jefferson, and less notably in other localities of the Eastern Division of the State. The chief forms in which these appear are *calamine,* and *electric calamine.* Sulphuret of zinc, or *Zincblende,* also occurs, but in inconsiderable quantities. Both of the former ores are found in a large deposit known as the "Stiner belt," in Union County. A large manufactory formerly existed at Mossy Creek, Jefferson County, which was engaged in converting native zinc ores, found in that locality, into white oxide of zinc for paint.

25. *Gold.* In one locality only of Tennessee has gold been found—on Coka Creek, in Monroe County. Mining operations were conducted here for nearly ten years, commencing in 1831; but the yield of the precious metal, never large, gradually diminished till its want of remuneration closed the mines.

Name other localities. Is lead found in Middle Tennessee? Where are ores of Zinc found? What are these ores termed? Where is the Stiner Belt? What manufactory of Zinc existed, and where? Where has gold been found in Tennessee? How long was mining conducted here? Why discontinued? What is said of the

26. *Coal.* This mineral, more valuable to man than gold, occupies a broad belt across the State of Tennessee, comprising an area of 5,100 square miles. It embraces the counties of Scott, Morgan and Cumberland, the greater parts of Fentress, Van Buren, Bledsoe, Grundy, Sequatchie and Marion; lesser portions of Claiborne, Campbell, Anderson, Rhea, Roane, Overton, Hamilton, Putnam, White and Franklin, and small portions of Wayne and Coffee. It embraces, indeed, the whole area of the Cumberland Table-land, and constituting our sixth geological division of the State, and lying partly in East and partly in Middle Tennessee. It is a part of the great Appalachian coal-field, reaching from Pennsylvania, in the north-east, to the neighborhood of Tuscaloosa, Alabama, in the south-west, including a total area of about 80,000 square miles.

27. The coal found in the coal region of Tennessee is all of the kind denominated *Bituminous* coal, embracing most of the varieties of this species mentioned in the preceding chapter. A large number of coal mines, scattered throughout this region, convenient to navigable streams and railways, are in active operation.

28. In almost every part of this region in our State, coal may be found in strata of greater or less thickness. Often these strata lie one above another,

value of Coal? What region does it occupy? Its area? What geological division does it embrace? What Counties? Of what great Coal Field is it a part? Area of this great Coal Field?

with interposed beds of sandstones, shale, conglomerate, and other materials; in which case they are termed *coal measures*. These strata vary in their thickness from a few inches to as much as eight feet.

29. Coal mines are in active and profitable operation in the counties of Grundy, Marion, Hamilton, Roane, Rhea, Anderson and Campbell; and scientific analysis has shown that some of these coals have contained as much carbon as eighty-two per cent. Railroad enterprises now in progress will speedily open many other mines.

Beds of *lignite* exist in some localities in all of the three divisions of the State. Although somewhat combustible, it does not contain enough carbon to be useful as a fuel.

30. *Marble.* Tennessee is favored with a profusion of fine marble, liberally bestowed on each of the three great divisions of the State. It is largely employed in the useful arts, and displays a great variety of colors and many beautiful figures, when polished. Specimens of the marble of East Tennessee may be seen among the decorations of the Capitol in Nashville, the National Capitol, Washington City, and in the Custom House in Knoxville.

What kind of Coal is found in this region? What are *Coal Measures*? What rocks are interposed between the coal-beds, or strata? What thickness have these strata? In which counties are Coal mines in active operation? What proportion of Carbon do these coals afford? Will other mines be opened soon? By what agency? What is said of beds of Lignite? In what Divisions of the State is Marble found? How is it employed? What appearances does it

31. *Limestone* is also found in each of the three great divisions of the State, chiefly in Middle and East Tennessee. Aside from its use when converted by heat into quick-lime, it is employed in architecture and other arts, as in the construction of walls, fences and pavements. The Capitol of the State, at Nashville, is built of a handsome and durable laminated limestone, quarried in the immediate vicinity.

32. In addition to the foregoing, we may add that valuable *Sandstones*, useful for building purposes, are found in great profusion in East and Middle Tennessee, and in some portions of West Tennessee; and that excellent *potter's clay* and *fire clay* have been found and utilized in the several divisions of the State.

33. *Black Oxide of Manganese*, useful in many of the arts, and employed in converting iron into Bessemer steel, is found in greater or less quantities in various parts of the State, most usually in close proximity with iron.

34. *Sulphate of Baryta*, or *heavy spar*, is found in Middle and East Tennessee. It is mined in Greene, Washington, Jefferson and McMinn Counties, and is ground to powder, making a cheap white paint for houses.

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display? Where may specimens of its use as decorations be seen? In what Division is Limestone found? To what uses is it applied? What notable public building is constructed of it? Where quarried? Where are valuable sandstones found? For what purposes are these useful? Where are useful Potter's Clay and Fire Clay found? Where is Black Oxide of Manganese found? For what is it useful? Where is Sulphate of Baryta, or Heavy Spar, found?

35. *Common Salt* was obtained many years since, at Winter's Gap, in Anderson County, by Prof. Joseph Estabrook, President of East Tennessee University; also, other wells were bored successfully in the counties of White and Overton. The manufacture of salt may yet be made profitable in those localities.

36. *Saltpetre* is found in the caverns which abound in Middle and East Tennessee.

37. *Petroleum* has been obtained by borings in Overton County, in two localities.

38. *Copperas* abounds in conjunction with the shales, cropping out on the margin of the Highland Rim. It is used in a crude state for domestic purposes. *Alum* is found in the same situations.

39. *Epsom Salt* is frequently found in limestone caverns in Middle and Eastern Tennessee. A locality in Sevier County, named Alum Cave, contains Epsom Salt plentifully.

40. *Bluestone* is one of the forms of copper found at Ducktown, constituting an article of well-known use in the arts.

41. *Mineral Waters.* Tennessee abounds in mineral waters, many of them possessing important curative properties and attracting large patronage. Some

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Where is it mined, and for what is it used? Where has Common Salt been found? Where is Saltpetre found? Petroleum? Where is Copperas found? In conjunction with what? How and for what is it used? Where is Alum found? Where is Epsom Salt found? Blue Stone? What is said of the Mineral waters of Ten-

of these are provided for entertaining large numbers of visitors, and are annually thronged with people seeking health and pleasure.

42. These mineral resources of Tennessee are of incalculable value to the State. Especially is this true of the metallic ores, which, as we have seen, are found in great abundance. Aside from the direct demand for skilled labor which the art of mining these ores creates, they give rise to other arts—as metallurgy, for instance—and many important manufactures. They likewise indirectly exert a most salutary influence upon other industrial pursuits.

Undoubtedly the most valuable minerals, in this respect, found in the State, are coal and iron ores. The amount of coal annually mined in the State at this time is perhaps not far from half a million tons, representing a valuation of perhaps one million five hundred thousand dollars. The amount still remaining deposited within the borders of the State is, perhaps, beyond calculation, but is, without doubt, enormous. Rough calculations have estimated that at least forty thousand millions of tons are available for future uses.

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nessee? Do the Tennessee mineral waters attract visitors? Of what value are these mineral resources? Which are most valuable? To what useful ends does mining lead us? What other influence do these arts exert? Which are the two most important minerals of Tennessee? What amount of Coal is now annually mined in this State? What is its approximate value? Can we estimate the remainder? What conjecture is given on this subject? What adds

43. The great and ever-increasing uses to which iron is applied render it a most important and valuable metal. The occurrence of beds of iron ore under favorable conditions in the State, gives rise to many important industries, of great value to the commonwealth.

44. The manufacture of iron may, generally, be divided into three distinct branches. The products of these are cast-iron, wrought-iron, and steel. In these three distinct forms the metal is made use of in the arts. The differences in physical properties of these products are well known. They also differ from each other in their chemical relations. Thus, *wrought* or *soft* iron is pure metallic iron; steel is metallic iron chemically united to a small proportion (one to two per cent.) of carbon; cast iron is metallic iron containing more carbon (three to five per cent.) than steel. The three all contain, generally, small proportions of impurities, the most important and deleterious of which are phosphorus and sulphur—the one rendering the metal "*cold short*"—brittle when cold—and the other "*red short*"—brittle when red hot—both thus interfering seriously with the working of the metal.

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to the importance of Iron? To what do the Tennessee Iron-beds give rise? Into how many branches may the Iron-manufacture be divided? What are the products of these? In what are these several products used? In what respects do these products differ? What is wrought, or metallic iron? What is steel? Cast iron? Do these contain impurities? What? What effect has the phos-

45. Of these three products, cast-, or *pig*-iron, is always made first. It is obtained directly from the ores of iron, by heating these in a *blast furnace*, with charcoal or coal as fuel, which reduces the ore to the metallic state, the metal at the same time uniting with the requisite amount of carbon (from the fuel) to form cast iron. In order to remove the siliceous and other impurities always associated with the ores, there is added, before smelting in the furnace, a small portion of *flux*—which is generally limestone—which unites with the impurities, forming a fusible slag, in which form they are removed.

46. The ores occurring in this State possess the following among other characteristics:

1. They are *easy* to work; that is, are readily reduced in the furnace.

2. They are generally quite free from phosphorus and sulphur, and other deleterious impurities.

3. They occur generally not far from deposits of coal and limestone (often, indeed, intimately associated with these), the ore, fuel, and flux being thus all within easy reach of the furnace.

In addition, the beds of sandstone and fire clay which we have seen to exist in considerable quantities

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phorus? The Sulphur? Which of these products is first made, and from what? How? Whence comes the carbon to unite with the iron to make pig-iron? What is added to remove impurities? What is *flux*? With what does it unite? What is the product of fluxing termed? Is this product valuable? What is the first characteristic of the Tennessee iron-ores? The second? The third?

in the State, furnish excellent materials of which to construct the blast furnaces.

47. There are perhaps at this time not less than twenty blast furnaces in operation in the State, producing annually as much as eighty thousand tons of pig-iron, with a valuation of perhaps two millions of dollars.

48. By far the greater part of the pig-iron made is exported beyond the borders of the State; the manufacture thus stimulates commerce, and is a source of actual revenue. A number of *foundries* are established, however, at the several industrial centers throughout the State, which re-melt the pig-iron, and cast it into the various shapes in which it finds application.

49. Wrought-iron is made from pig-iron, by heating this in a *puddling* furnace in such manner as to burn out the carbon which it contains, and leave the metal pure and soft. Wrought-iron is worked into shape by rolling and hammering. A number of puddling furnaces and rolling mills are established at various points in the State—such as Chattanooga, Knoxville, etc.—which manufacture quantities of bar,

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What other? How many blast-furnaces are now in operation in Tennessee, probably? What the probable annual product? Of what value? What is done with the greater part of this pig-iron? What other branch of human industry does this stimulate? Where are iron-foundries established? What function do foundries perform? From what is wrought-iron made? How is it effected? How is wrought-iron worked into shape? What is said of the location of puddling-furnaces and rolling mills in Tennessee?

sheet, and boiler iron, and other useful articles for which wrought-iron is employed.

50. Steel is made, also, from pig-iron, by subjecting it to *partial* decarbonization. Various processes are in use for this purpose. The amount of steel now manufactured in Tennessee, if any, is inconsiderable.

51. It would be, perhaps, impossible to estimate the amount or money value of the ores of iron yet remaining (many, indeed, not yet located or explored) within the State. It is enough to say that, in either case, the estimations, to approach the truth, would certainly reach enormous figures.

52. Copper, perhaps, ranks next to iron among the valuable metals found in the State. We have already described its ores, and the localities where they are found. The copper ores are generally smelted, or *reduced*, directly at the mines, and the metal—in the form of *ingot copper*—is in great part exported. The amount of copper now produced annually in the State is, perhaps, not far from two million five hundred thousand pounds, with a valuation of five hundred thousand dollars.

What manufactures are here produced? From what is *Steel* made? How? By one, or various processes? Is much steel manufactured in Tennessee? Can any accurate estimate of the value of Tennessee iron ores be made? What is remarked of their value? How does Copper rank among Tennessee's valuable minerals? How are Copper ores converted into metallic copper, and where? What is done with the Copper? In what form and what termed? What amount of Copper is annually produced in Tennessee? Value?

53. Of the other metals and minerals found in the State, their uses and value have already been briefly pointed out.

54. From what has been said above, it will readily be seen of how much value to the State are its mineral resources. And this value is measured, not alone by the intrinsic worth of the minerals themselves, nor yet by the important manufacturing and other industries to which they directly give rise. Their further importance is seen in the influence which they indirectly exert upon commerce, called upon to transport the products of the manufactures; upon agriculture, called upon to supply the needs of the many human beings employed in these industries; and, in fact, upon all other branches of industrial occupation to which men turn their labor and attention. These industries, taken collectively—their relations to each other being judiciously preserved—make up the wealth, mark the intelligence and determine the growth of an opulent, progressive and thrifty commonwealth.

What will readily be seen from the facts stated? How is this value measured? What further importance do these mineral resources possess? How is Commerce stimulated? How is Agriculture fostered? What do these several industries collectively effect?

CHAPTER VI.

GENERAL DESCRIPTION OF USEFUL MINERALS AND ORES.

1. It may be well for us to study, in this place, something concerning the forms in which certain useful minerals and metals occur in nature, and the properties of those which serve to identify them. The useful minerals do not occur in nature, as a rule, in a free, metallic state. They usually occur chemically combined with certain non-metallic, chemical substances—such as oxygen, sulphur, and carbonic acid—forming what are called *ores*. In the practical signification of the term, an *ore* is a mineral occurring in nature, containing a useful metal in such form and under such conditions as will permit it to be extracted with profit.

2. Commonly, the metallic ores do not occur spread out over the surface of the earth in the form of rock-beds, covering large areas of country. Their usual mode of occurrence is in the form of *veins*, of greater or less extent, formed as described in a previous chapter; in these, they are asssociated more or less with other mineral matter.

What is the subject of this Chapter? What is it well for us to study next? How do useful minerals generally occur in Nature? Forming what? What is an ore? Do ores occur in the same form as rock-beds? Describe their usual mode of occurrence. With

3. Occasionally the metallic ores occur in other forms than veins—such as huge, isolated masses, (the case frequently with iron-ore); small beds, which appear to be truly and regularly stratified; in grains disseminated through certain stratified rocks; and in fragments, of various sizes and and in various degrees of profusion, scattered through alluvial deposits and the sands of the beds of streams.

4. The proportion of the earth's surface occupied by deposits of metallic ores, it will be observed, is a *very* small one.

5. We shall take up the chief useful metals in regular order, and briefly describe the characters of their principal ores.

1°. *Iron.* There are four principal ores of iron—

(*a*) *Magnetic Oxide*—(commonly called "loadstone"). This is a heavy, black ore, usually hard and compact. It is strongly attracted by the magnet, and, if scratched with a knife, the *streak* is *black.* When perfectly pure, it is capable of yielding seventy-two per cent. of metallic iron. The ordinary yield, however, is only from thirty-five to sixty per cent.

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what are they associated? How otherwise than in veins do metallic ores occur? What proportion of the earth's surface do metallic ores form? In what order shall we proceed in our researches? How many principal ores of iron? What are they? The first? Describe Magnetic Oxide, or loadstone. When scratched, what color has the streak? When pure, what is the yield? What the

(*b*) *Red Oxide.* This occurs in two forms—*crystallized* and *massive.* The crystallized (called Specular Iron Ore), is a bright, highly lustrous ore, of a dark, steel-grey color, occurring frequently in very beautiful crystals. The *massive* form (called Red Hematite), is a dull, red colored variety, sometimes compact, and sometimes fibrous, in character. This ore is less heavy and hard than the magnetic oxide; gives a red streak when scratched, and is capable of yielding, when pure, seventy per cent. of metallic iron. The ordinary yield is from forty to fifty per cent.

(*c*) *Brown Oxide.* This ore occurs in a variety of forms; crystallized (to a slight extent only), compact and massive (when it is called Brown Hematite), in small, rounded grains, loose or conglomerated (called *pea iron ore*), and mixed with clay and other impurities, forming great soft beds of *yellow ochre.* It is usually a soft ore, of a brownish color, producing a yellow streak, and, when crushed, a yellow powder. It is capable of yielding, when pure, sixty per cent; of metallic iron, the actual yield is usually much less than this.

(*d*) *Carbonate of Iron.* This occurs crystallized (called Spathic Iron Ore), and massive, associated

ordinary yield? What are the forms of the Red Oxide? Describe each. Which is crystallized? How may the Red Oxide be distinguished from the loadstone? What is the metallic yield of the Red Oxide? In what forms does the Brown Oxide of iron occur? When is it called Brown Hematite? When Pea Iron Ore? When Yellow Ochre? Describe the general appearance of Brown Oxide. What is said of its yield? How does Carbonate of Iron, or Spathic

with beds of clay, called clay ironstone. It is usually of a light brown or grey color, having a pearly lustre, and is softer and lighter than either of the other ores mentioned. The color of the ore varies, however, being sometimes nearly black, and it occurs in all degrees of impurity. It is frequently associated in beds with seams of coal. When pure, it will yield as much as forty-seven per cent. of metallic iron, but the practical yield rarely exceeds twenty-five or thirty per cent.

Besides these four principal ores, there are others of less importance, which occur in limited quantities. There are also certain compounds of iron which, technically considered, are not *ores* of the metal. *Iron pyrites* is a compound of iron and sulphur, occurring sometimes massive, but usually crystallized in the form of a cube or octahedron. The mineral varies in color from a golden yellow to a silver white. From being frequently mistaken for gold, it has received the name of *fool's gold.* It is hard and brittle, and strikes fire with steel; and this fact will serve to prevent persons from mistaking it for gold. Though containing forty-five per cent. of iron, good metal cannot be extracted from it with profit. It is

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Iron Ore, occur? Describe it. What colors does it present? Is it always pure? With what is it occasionally associated? What is its yield? Are there other Iron ores? Compounds? What is Iron Pyrites? How usually crystallized? What colors does this mineral display? What name has it obtained, and why? What are its properties? Can it be manufactured profitably? For what

used as a source of sulphuric acid and alum. When exposed to the weather, it undergoes spontaneous decomposition, and forms, with its associated rocks, copperas and alum.

There are three principal iron regions in Tennessee, all of which form *belts* extending entirely across the State. One of these lies along the western border of the Unaka Chain; another along the eastern base of the Cumberland Table-land, extending into the Valley of East Tennessee; another, yielding *clay ironstones* co-extensive with the coal measures on the Cumberland Table-land, and the fourth along the western edge of the Highland Rim, including a part of the Western Valley. The ores which occur in these regions are chiefly the Magnetic, Red and Brown Oxides; and in all these localities, excepting the Cumberland Table-land, where the character of the ore is less remunerative to the manufacturer, manufactories are actively at work in the production of iron. and are rapidly increasing.

I. *Copper.* The chief ores of copper are six in number.

(*a*) *Copper Pyrites.* This is the most abundant and important ore of copper. It occurs generally in a

purpose is it used? How does exposure affect it? Decomposed, what does it form? How many principal iron regions in Tennessee? What do they form? Where are these located? Are there other smaller veins and deposits of iron? Where? Of what kinds are the Tennessee ores? How many chief ores of Copper are there? Which is the most abundant? How does it occur? What its qualities and appearance? Of what is it composed? When pure

crystallized form, but sometimes in masses of various shapes. It has a bright yellow color and high metallic lustre. It is brittle, and resembles in appearance iron pyrites, but differs from this mineral in being much softer, and in not striking fire with steel. It is composed of copper, iron, and sulphur, and will yield, when pure, thirty per cent of copper. The practical yield is generally much less than this, and it can be worked with profit when it contains only six or eight per cent.

(*b*) *Purple Copper* is a reddish-brown ore, sometimes purple or red. It occurs usually crystallized in cubes, consisting of copper, iron, and sulphur, and will yield fifty per cent. of copper.

(*c*) *Sulphide of Copper* has a greyish color, resembling iron, and is often iridescent. It occurs both crystallized and massive, consists of copper and sulphur, and will yield seventy-five to eighty per cent. of metal.

(*d*) *Oxides of Copper.* There are two ores of this class—the red oxide and the black oxide. The former is a blood-red or brownish ore, with a reddish-brown streak. The latter is a black ore, which soils the fingers, and gives a black streak. Both are quite heavy; they yield from eighty to ninety per cent. of copper.

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what will it yield? When can it be worked with profit? What is Purple Copper? How does it usually occur? Of what does it consist? What will it yield? Describe Sulphide of Copper. What are its constituents? Its yield? How many Oxides of Copper? What are they called? Describe them. What will they yield?

(*e*) *Carbonates of Copper.* Of these there are two: the *blue* carbonate, called *azurite;* and the *green* carbonate, called *malachite.* These occur in nearly all deposits of copper, associated with other ores. They are generally in the form of small, tabular masses, occasionally crystallized. Large masses are sometimes found, but these are rare. Both ores are of light weight and quite soft, giving a blue and green streak respectively. The finer specimens are used in the manufacture of jewelry. These ores yield about fifty-five per cent. of copper; they are generally worked along with other ores.

(*f*) *Native Copper.* By this is meant the metal in a free metallic state occurring in nature. This ore has the appearance and properties of the ordinary metal, so that it is easily distinguished. It has been found in large masses of more than a ton's weight, but it usually occurs in small particles, associated with other ores.

There are a few other ores of copper, which, however, are of little importance.

The only localities in Tennessee where copper in any quantity has been found, is in the region of Ducktown, in the metamorphic rocks of the Unaka chain,

How many Carbonates of Copper? What are their names? In what form usually found? In what rarely found? How may they be known by weight and other properties? For what are fine specimens used? What will they yield? How are they generally worked? What is meant by Native Copper? What appearance has it? How is it found? Are other ores of Copper important? How do such occur? Where has Copper been found in Tennessee?

to be hereafter described. Nearly all the ores above mentioned occur in this locality.

III. *Lead.* There is but one principal ore of this metal, viz: *Galena,* which is a compound of lead and sulphur. This is a very heavy, dark colored ore, usually of a leaden-grey or blackish-grey color, having a high metallic lustre. It is soft and somewhat malleable, and has a dull, black streak. It will yield about eighty-five per cent. of metallic lead, and is usually found quite pure. Galena almost always contains silver, but usually in minute quantities.

The *carbonate of lead,* and a few other ores of this metal, also occur to some extent. The former is a soft, light-colored ore, usually white or yellow, with a peculiar lustre. It occurs in fibrous and compact masses, and will yield, when pure, seventy-eight per cent. of metal.

Galena occurs at numerous points in Middle and East Tennessee, but generally in small quantities only.

IV. *Zinc.* There are four principal ores of zinc.

(*a*) Carbonate of Zinc (or *calamine*). This is the most important and abundant ore of zinc. It is a

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Do these ores described all occur in Tennessee? What is Galena? Of what composed? Describe it. What will Galena yield in metallic lead? How usually found? What other metal does Galena almost always contain? What other ores of lead are mentioned? Describe Carbonate of Lead. How does it occur? What will it yield? Where does Galena occur? In what quantities? How many principal ores of Zinc are there? What is Carbonate of Zinc or Calamine? Describe it. Of what does it consist? What

somewhat heavy ore, soft and usually crystallized, though it frequently occurs massive. It is light-colored, being colorless, white, grey, green, or brown, and has, in all cases, a white streak. It consists of the oxide of zinc and carbonic acid, and will yield about fifty per cent. of metal.

(*b*) Hydrated Silicate of Zinc (or *electric calamine*). This is a compact, light-colored ore, of white or yellowish shades usually, having a white streak and a glassy lustre. It is a soft ore, and somewhat less heavy than calamine. It is distinguished by the property of becoming electric by heating. It consists of the oxide of zinc, silicic acid, and water, and will yield about fifty-two per cent. of metal.

(*c*) *Zincblende* is a dark-colored ore, usually black or brown, but sometimes found of yellow, red or green color. Its streak is white, inclining to reddish-brown. It is brittle and somewhat heavy. It is composed of zinc and sulphur, and, as usually found, yields about sixty-five per cent. of metal.

(*d*) Red Oxide of Zinc. This is a heavy, light-colored ore, usually found in compact masses, somewhat hard, and having a white streak. It yields usually about seventy-five per cent. of metal.

Zincblende and several other ores occur at various localities in Tennessee, generally associated with

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will it yield? Describe Hydrated Silicate of Zinc, or Electric Calamine. How is it distinguished? Of what does it consist? What will it yield? Describe Zincblende. Of what composed? Its yield? Describe Red Oxide of Zinc. How found? What will

galena. Large deposits of zinc are found in Claiborne, Jefferson, and Union Counties in Tennessee.

V. *Gold.* There is but one form in which this metal occurs in nature, viz: as free, metallic gold, found either imbedded in veins of quartz and other mineral matter, or mixed with the sand of streams in fine grains, or in nuggets of greater or less size. Gold always occurs *native.* It may be readily known by its rich, yellow color, by its great weight, malleability, softness, and insolubility in strong acids. These properties serve to distinguish it from several minerals which it resembles, and which are frequently mistaken for it.

Small quantities of gold have been found in Tennessee, especially in the south-eastern part of the State, on Coca Creek, in Monroe County.

The only mineral of especial value, besides the metallic ores above described, that we shall mention in this place, is mineral coal.

VI. *Mineral Coal.* This very interesting and important mineral is believed to have been formed in nature by the decomposition of vegetable matter—the wood of trees, &c.—by which some of its constituents were driven away, and a portion (chiefly *carbon*)

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it yield? What ores of Zinc occur in Tennessee? Where and how? How is gold found in Nature? How does it always occur? How may it be known readily? Do any other minerals resemble gold? Has gold been found in Tennessee? In what part of the State? In what quantities? How is Mineral Coal believed to have formed? Is such decomposition now going on? Where? What would

left behind. Such decomposition can now be seen to be going on in the masses of vegetable matter found in the beds of swamps and marshes. Subsequent pressure brought to bear upon a mass of such carbonaceous matter would consolidate it into a *bed* of greater or less thickness.

There are three principal varieties of coal which seem to exhibit the character of this decomposition and transformation.

1. *Lignite,* or *Brown Coal.* This variety preserves some traces of its woody nature, being fibrous, and in structure somewhat like wood. It is light in weight, of a brown color (sometimes nearly black), is brittle, devoid of lustre, and burns easily, leaving a white ash.

2. *Bituminous Coal.* In this variety the woody structure is entirely effaced, and the color and appearance indicate an advanced state of decomposition. The coals of this variety are all soft, and contain more or less of a soft, inflammable, mineral substance, called *bitumen.* For this reason they all burn with a *flame.* Various names are given to the coals which belong to this variety.

(*a*) *Coking Coal* is moderately compact, brittle, and

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compress this into a bed? How many varieties of coal? What do they exhibit? Describe Lignite, or Brown Coal. What is said of Bituminous Coal? Is a woody structure visible? What inflammable mineral substance does it contain? What effect does this have on their burning? What is Coking Coal? Describe its properties. How does it burn? What tendency has it? Describe

has a somewhat resinous lustre. When heated, it at first flies to pieces, but afterwards fuses (*cokes*) to a pasty mass, which soon hardens into a compact mass. It burns with a yellow flame, which is not continuous, because of the tendency to *coke*.

(*b*) *Splint*, or *hard coal*, is hard, brittle, of a black color, and a glistening lustre. It is hard to kindle, but burns with a fine, clear fire.

(*c*) *Cherry*, or *soft coal*, is much like coking coal, but is more brittle, has a splendent appearance, and does not fuse when heated. It readily ignites, and gives a clear flame.

(*d*) *Cannel, candle*, or *parrot coal*, is compact and even, of a shining lustre, and jet black, or brownish black, in color. It is brittle, and flies to pieces when heated, but ignites readily, and burns with a clear, yellow flame, like that of a candle.

3. *Anthracite Coal.* In this variety all traces of its vegetable origin have been destroyed. It represents the last stage of vegetable decomposition. It is a hard, compact substance, of black color, very lustrous, and often iridescent, and less brittle than the bituminous. It contains little or no bitumen, is very difficult to ignite, and does not burn with a flame, but *glows*. It is sometimes called *glance*, or *stone coal.*

Splint, or Hard Coal. Does it kindle easily? Describe Cherry, or Soft Coal. How does it ignite and burn? Are traces of vegetable origin seen in Anthracite Coal? What does it represent? Describe it. Does it contain bitumen? How is it ignited? How does it burn?

The greater part of the coal found in Tennessee is bituminous in character. Its localities are elsewhere described.

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CHAPTER VII.

THE HISTORY OF THE ROCKS, IN POINT OF TIME.

1. It is very evident, from what we have learned in the preceding chapters, that all the rocks which make up the crust of the earth, as we now find it, were not formed at the same time. This is especially true of the stratified rocks, since these were made by the action of the seas—building up at one time a stratum of one kind of rock, and at another, of a different kind, placing one upon the other.

2. For in the various formations heretofore described, we find strata of different kinds of rocks—such as limestones, sandstones, conglomerates, &c.—built up on each other in regular order. It would appear evident, that in a series of strata, that stratum which is lowest in position is oldest in point of age,

What other name is it known by? What kind of coal is found in Tennessee? What is the subject of Chapter Sixth? Were all the rocks formed at the same time? By what processes were stratified rocks formed? In what succession are they found built up? Which stratum is the oldest of any series? What is important in

since it must have been formed before those which have been deposited upon it.

3. Since the stratified rocks occupy the greater part of the surface of the earth, the study of the age of each of these is very important. It is one object of geology to determine the relative times of formation of the rocks which constitute the crust of the earth.

4. The stratified rocks were, for the most part, formed, as we have seen, by the action of the seas, breaking down and building up in another form the unstratified. An uninterrupted process of this sort would have resulted in the formation of a succession of beds, placed one above the other, the first formed being lowest in the scale. The relative ages of the rocks could then have been easily determined by their relative positions.

5. But the processes of stratification did not, as we have learned, go on without interruption. Strata once formed were uplifted, folded, and distorted, themselves denuded, broken down, and their material used in the formation of new strata. Ejection of igneous matter from the interior of the earth occurred at various times, providing new material for the formation of new strata by the ceaseless action of the seas.

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studying stratified rocks? What is here mentioned as one object of Geology? How did the action of the seas form the stratified rocks? What would this process, if not interrupted, have produced? How could the relative ages have been determined? Did the process go on uninterruptedly? What violence happened to the strata? What influence of igneous matter were they subjected

6. A careful study of the rocks enables us to determine the order in which these events occurred, and thus to establish the history, in point of time, of the rocks as they now exist. There are three points connected with the rocks which furnish information as to their relative ages.

1°. *The order in which the strata are placed upon each other.* Notwithstandiug the great disturbances and changes to which they were subjected, the strata frequently give much information as to their relative ages by their order of arrangement.

2°. *The character of the rock.* Although the same kinds of rocks were found at different periods, yet the composition of a rock frequently determines its source, or the rock from which it was made; and if the age of the latter is known, that of the former may be, in part, inferred.

3°. *Fossils.* In almost all sedimentary rocks there are found relics of ancient life, both animal and vegetable. These are termed *fossils.* They comprise the bones, shells, and other remains of animals, and the leaves, stems, and other parts of plants. Frequently, where no fossils themselves are found, impressions of their forms are found imprinted upon the rocks. It generally happens that fos-

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to? What does careful study of the rocks enable us to do? How many points furnish information of their relative ages? What is the first? What the second? How may inferences be drawn from the rock's character? What is the third? What are termed *fossils?* What do fossils comprise? What are impressions? Is it

sils are of such character as to determine at once the animal or plant to which they belonged. At other times, only parts of the bodies are found, such

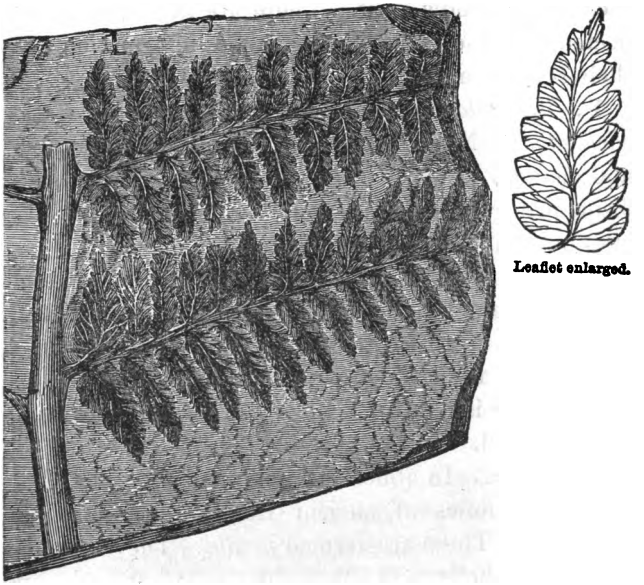

Fig. 12.—A Carboniferous Fern (Sphenopteris Egyptiaca).

as the single leaf of a tree, or the scale of a fish. In such cases, the skillful anatomist is generally able to form opinions as to the nature of the plant or animal represented by these relics, and, in some cases, to reconstruct them artificially. The information

easy to determine the character of a fossil? What is shown in the illustrations? May the character of a plant or animal be known from a *part* only? What knowledge is gathered from fossils?

given by these fossil remains as to the ages of the rocks in which they are found, is highly important; and it is, in fact, mainly upon this means that geologists rely to make out the history of the rocks. Let us examine the nature of the assistance they afford in this respect.

If a rock be found containing great numbers of fossils of a particular kind, it is evidence that the animals or plants represented by these fossils existed upon the surface of the earth at the time when the rock was formed. The study of the nature of these animals or plants would disclose the peculiar conditions of atmosphere, climate, etc., that must have existed upon the earth when they possessed life. If, now, another rock should be found filled with similar fossils, it would be evidence that this was formed, either at the same time as the first, or when similar conditions existed. Other rocks, containing a different class of fossils, would evidence the necessity for different conditions on the earth's surface, to permit the existence of the beings represented by the fossils. The history of the rocks is, therefore, intimately connected with the history of the *life* that has existed at different times upon the earth.

The fossils that have been found in the rocks repre-

What do numerous fossils of a particular kind show? What would the study of them disclose? What would similar fossils found in another rock show? If the fossils were different, what would be the inference? With what is the history of the rocks intimately connected? What do all the fossils known show? Are the forms

sent a great variety of life. The greater number of the forms have no existence at the present time, as they existed in previous ages. Some of them have become entirely extinct. Others still exist, but under such modified conditions that they bear but little resemblance to those of ancient times. Thus, though *fishes* existed in large quantities in some of the past geologic ages, they were generally very unlike in appearance to those now found in the waters of the earth.

7. From a careful and long-continued study of the rocks themselves, and of the fossils which they contain, geologists have arrived at the following conclusions, which embrace the principles that are applied to determine the age of any particular rock relative to all the others. The principles yield, in their application to all the rocks, a connected history of the events and processes which, in proper order, gave to the earth's crust its present appearance.

1°. *Life upon the earth has been progressive.*

The first life that existed upon the earth was in the form of the lowest orders of animals and plants. This was followed by a progressive succession of higher and higher forms of life, until all orders and degrees of development had been reached in their

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of life now the same? What is remarked of the fishes? Whence have conclusions to follow been drawn? What connected history is derived therefrom? Has life on the earth been stationary? What was the first form of life on the earth? How did others follow? How was the highest point attained? What classification

turn, and the highest point finally attained by the occupancy of the earth by man.

It is especially in consequence of this conclusion, or principle, that we class together, chronologically, rocks which exhibit identity in the character of their fossil contents.

8. It will be necessary for us at this time to take a hasty glance at the various *orders*, or sub-divisions, into which the different forms of life of the animal and vegetable kingdoms have been divided, in order to understand the divisions to which these have given rise in the history of geologic time.

A. THE ANIMAL KINGDOM.

There are four different types of animals, in accordance with one or other of which all are constructed. Each type is susceptible of great variety, which is fully recognized in nature. These form the great "sub-kingdoms" of animal creation, as follows, beginning with the lowest:

1. *Radiates.* These have a *radiate* structure, like a star or flower, around a central axis. There are three classes—

(*a*) Echinoderms—having a spiny covering, like a hedge-hog skin. They are divided into three orders:

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of the rocks does this lead us to? What is necessary for us next to glance at? How many types of animals are there? Has each type great variety? What do these form? What are Radiates? How many classes of them? What are Echinoderms? Into how many orders divided? What are their names? What are Aca-

(1) Echinoids, (having a hard shell); (2) Star fishes, and (3) Crinoids, (growing on a stem like a flower).

(*b*) Acalephs—soft, jelly-like animals.

(*c*) *Polyps*—fleshy animals, like a flower, having a central mouth, with arms surrounding it. The bones of this animal form the coral.

2. *Mollusks.* These have a soft sack, usually inclosed in a hard shell. The common oyster is a mollusk. There are six classes—Cephalopods (head-footed); Gasteropods, (body-footed); Pteropods, (wing-footed); Brachipods, (arm-footed); Conchifers and Bryozoans, (moss-like animals). The Brachiopods and Conchifers are enclosed in a double shell, and are hence called *bivalves.*

3. *Articulates.* These have a jointed structure, made up of a series of rings. There are three classes: Insects, Crustaceans, and Worms. The Crustaceans are enclosed in a shell, as the crab.

4. *Vertebrates.* This is the highest type, and is distinguished by having an internal jointed arrangement, usually of small bones, called a *back-bone.* There are four classes: Mammals, (which suckle their young); Birds, Reptiles, and Fishes. There are three orders of fishes: Teliosts, Ganoids, and Selachians.

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lephs? What are *Polyps?* What do their bones form? What are Mollusks? What are oysters? How many classes of Mollusks are there? What are bivalves? How are *Articulates* formed? How many classes of them? What is a crab? What are Vertebrates? How distinguished? What classes of Vertebrates are there? How

There is a class of animals called Protozoans, including the sponges and other similar animals, which seem to have no distinct plan of structure.

The highest form of animal life is, therefore, the *Mammal;* the lowest, the *Protozoan.*

B. The Vegetable Kingdom.

There is but one type of structure among plants—the *radiate.* There are two important sub-divisions in this kingdom:

1. *Cryptogams.* These have no distinct flower or fruit. There are three classes: *Thallogens,* (sea weeds, etc.); *Anogens,* (mosses, etc.); *Acrogens,* (ferns, etc.)

2. *Phenogams.* These have distinct flowers and seed. There are three classes:

(*a*) *Gymnosperms,* having simple flowers and *naked* seed, as the pine, spruce, etc. There are three orders: (1) *Conifers;* (2) *Cycads,* and (3) *Sigillarids.*

(*b*) *Angiosperms,* having regular flowers and covered seed, as the apple, elm, maple, etc.

(*c*) *Endogens,* having regular flowers and seed, but without bark, and with no rings of growth; such as palms, reeds, grasses, etc.

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many orders of fishes are there? What are Protozoans? What is the highest type of life? What the lowest? How many types of vegetable structure? What is it? What sub-divisions are there? What are Cryptogamous plants? Into what three classes are they divided? What are Phenogams? How many classes of them? What are Gymnosperms? What orders are they divided into? What are Angiosperms? What are Endogenous plants? What

2°. From the first appearance of life upon the earth, as various forms—higher in their order of structure than those which preceded them—followed each other in regular order of succession and development, it appears that there were certain great periods of time characterized by the prevalence of certain forms of life, in great excess over all others. The excessive prevalence of certain types of animals or plants, throughout certain periods, is accepted as a second well-sustained conclusion deduced from the examination of the rocks, and as a principle to guide geologic study and research.

Historical Geology (as this branch of our study is termed), is therefore divided into a number of sub-divisions, called *ages*, corresponding to the periods of time characterized by the prevalence of certain distinct types of animal or vegetable life; and to these sub-divisions names are given, expressive of the several types then prevalent.

The *Azoic* Age denotes a period when *no life* existed upon the earth.

The *Silurian* Age, or Age of Mollusks, denotes a period when mollusks, in great variety, were the prevalent type.

The *Devonian* Age, or Age of Fishes, denotes the age when fishes were very abundant.

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is observed of the excess of certain forms of life at times? How does Geology reveal such excesses? To what does this guide us? What is Historical Geology? Into what is it divided? How are the Geologic ages designated? What is denoted by the Azoic age? What is denoted by the term *Silurian* age? The *Devonian* age?

The *Carboniferous* Age, or Age of Coal-plants, denotes an age when vegetation of all descriptions was very luxuriant.

The *Reptilian* Age, or Age of Reptiles, and the *Mammalian* Age, or Age of Mammals, denote periods when reptiles and mammals were the prevalent types of life.

The forms of life which were dominant in the three ages first mentioned after the Azoic, are very ancient in character, and present little or no resemblance, in most cases, to those forms of the same types which now exist. They are, therefore, grouped together under the name of the *Palæozoic* Time, a name signifying "ancient life."

The life of the Reptilian Age was more modern in its character than that of preceding ages; and it is therefore classed as the *Mesozoic* Time, (middle-life). The Mammalian Age produced the highest types of life that immediately preceded the advent of man upon the globe, and it is therefore termed the Cenozoic Time, (recent life).

Even during the several ages mentioned above, life on the earth underwent certain changes, among the dominant types, as well as among those of less importance. Certain orders of life, under the same type, were more prevalent at one time than another.

The *Carboniferous* age? The Reptilian? The Mammalian? What character had the forms of life dominant in the first three ages? Under what name are they grouped? What is the age of Reptilian life termed? The Mammalian? Why these names?

Moreover, at certain times in these ages, great events transpired, such as violent upheavals and distortions of strata already formed, or then forming. These put an end to the peculiar circumstances which existed in the past, and under which the strata were formed, and furnished a basis for a new work of formation which was to go on in the future.

The *ages* have, therefore, been sub-divided into smaller portions of time called *periods*.

The *periods* have also been sub-divided into portions of less duration, termed *epochs*. The names given to these periods and epochs differ in different countries, but they are generally derived from certain geographical localities near which occur strata of different rocks, containing the fossils or other evidences on the nature of which the divisions of time are based. The portions of time represented by the divisions are generally, however, in all cases the same. The following table exhibits the classification of periods and epochs, based, in the main, upon the geology of the northern part of the State of New York. This classification is now generally adopted for the entire United States, including the State of Tennessee, and is proper to be used in studying the Geology of Tennessee.

What changes went on within these several ages? What great events transpired? State the effect of these events. Into what are the Geologic *ages* sub-divided? How *periods* sub-divided? Whence are names of *periods* and *epochs* mostly derived? What does the following table exhibit? Where is this classification generally adopted?

Age	Division	Period	Epoch
I. SILURIAN AGE. (Age of Mollusks.)	Lower Silurian.	1. Potsdam Period	1. Potsdam Epoch.
			2. Caciferous Epoch.
		2. Trenton Period	1. Chazy Epoch.
			2. Trenton Epoch.
		3. Hudson Period	1. Utica Epoch.
			2. Hudson Epoch.
	Upper Silurian.	1. Niagara Period	1. Oneida Epoch.
			2. Medina Epoch.
			3. Clinton Epoch.
			4. Niagara Epoch.
		2. Salina Period.	
		3. Lower Helderburg Period.	
II. DEVONIAN AGE. (Age of Fishes.)		1. Oriskany Period.	
		2. Upper Helderburg Period	1. Canada Galli Epoch.
			2. Upper Helderburg Epoch.
		3. Hamilton Period	1. Marcellus Epoch.
			2. Hamilton Epoch.
			3. Genesee Epoch.
		4. Chemung Period	1. Portage Epoch.
			2. Chemung Epoch.
			3. Catskill Epoch.
III. CARBONIFEROUS AGE. (Age of Coal Plants.		1. Sub-Carboniferous Period.	
		2. Carboniferous Period.	
		3. Permian Period.	
IV. AGE OF REPTILES.		1. Triassic Period.	
		2. Jurassic Period.	
		3. Cretaceous Period.	
V. AGE OF MAMMALS.		1. Tertiary Period	1. Eocene Epoch.
			2. Niocene Epoch.
			3. Pliocene Epoch.
		2. Post-Tertiary Period	1. Glacial or Drift Epoch.
			2. Champlain Epoch.
			3. Terrace Epoch.

What is the first Age? How is it divided? What are the Periods of the Lower Silurian? Of the Upper? What are the Epochs of each Period? What is the second Age? Into what Periods divided? What are the Epochs of these Periods? What is the third Age? Into what Periods divided? What is the fourth Age? Into what Periods divided? What is the fifth Age? Into what Periods divided? Into what Epochs is the Tertiary Period divided? Into what the Post-Tertiary?

9. It must be remembered that there is no sharp line of demarkation between these divisions of geologic time so that we may tell exactly where one ends and the next begins. They fade into each other by degrees and imperceptibly, so that it is frequently very difficult, and sometimes impossible, to determine precisely from the fossils and other characters of a rock, to what epoch, period, or even age, it belongs.

10. And finally, we may say, that in the classification of geological portions of time, no attempt is, or can be, made to determine how many *years* or *centuries* is represented by each. The ages are merely relative to each other. Historical Geology is, therefore, more properly a history of *order* and *succession* than of *time.*

Are these Geological divisions of time sharply marked? How are they connected with each other? Is it easy to determine exactly where all objects belong? Are these divisions of Geologic time measurable by years or centuries? What relation have these ages? Of what, then, does Historical Geology properly consist?

CHAPTER VIII.

HISTORICAL ACCOUNT OF THE ROCKS OF TENNESSEE.

1. We have now studied the composition and structure of the rocks, and the principles and methods employed to determine their relative ages, and have presented a scheme or table of the ages, periods, and epochs, which serves to classify the rocks formed at different times. Let us now examine the character of the various physical divisions we have noted for the State of Tennessee, and apply what we have learned concerning rocks generally, to the particular rocks of the different sections.

I. *The Mississippi Bottom.*

2. The geological character of the surface of this division is very simple indeed.

It is covered with a horizontal stratum of rock which is nearly uniform in composition, and which has been formed during the most recent epoch of the age of man. It has been formed, in fact, by the deposition of mineral matter (called, in such cases, *detritus*), from the great river which courses through

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What is the subject of Chapter Seventh? What have we now studied? What shall we examine next? What is said of the Mississippi Bottom in Tennessee? With what is it covered? How was this formed? What is the geological name of the mineral matter composing it? What is this kind of formation called?

this section, during repeated overflowings and changings of its channel. Such a formation is termed *alluvial*, and is always found to some extent along the beds and banks of existing rivers. The Mississippi Bottom is a great alluvial plain, of strongly marked character. It contains but few fossils, and these are all of existing and modern types of life.

II. *The Plateau of West Tennessee.*

3. In ascending the bluffs which separate the river bottom from the Plateau, outcroppings of several distinct formations are encountered, all of which, however, belong to very recent times, and are included in the Post-Tertiary Period. The lowest of the formations consists of beds of laminated sands and clays, containing distinct, but small, beds of "lignite." This formation, which is about one hundred and fifty feet in thickness, has been termed the "bluff lignite," and outcrops at other points in the State. Above it lies a formation, from ten to fifty feet in thickness, called the "bluff gravel," consisting of beds of silicious sand and gravel. Similar formations, of the same age, are met with elsewhere in the State. The topmost formation that crowns the bluffs consists of a bed of light, ash-colored or yellowish *loam*, generally

Where found? What is said of the Mississippi Bottom? Has it many fossils? In what geological period is the Plateau of West Tennessee embraced? Of what does the lowest of these formations consist? How thick is the bed of lignite? What is it termed? What is bluff gravel? How thick, and of what does it consist? Are such found elsewhere in Tennessee? What is the topmost

silicious, but sometimes highly calcareous in character. The thickness of this formation—called the "bluff loam"—is from fifty to one hundred feet, along the face of the bluff.

But few fossils are presented by the formations named above, and these are of modern forms of life, and evidence the recent period to which the rocks belong.

4. Leaving the bluffs, and traveling eastward across the Plateau, for a distance of about twenty-five miles the surface is found to be covered with the bluff loam formation, furnishing a strong and fertile soil, well adapted to agricultural purposes, and, in many places, heavily timbered. At the distance mentioned from the bluffs, there are encountered extensive beds of light-colored sand, orange, yellow, white, and sometimes red, occasionally interstratified with the beds of light-colored clays. These are in some localities separated from the bluff loam by thin outcroppings of the "bluff lignite" formation. These beds run entirely across the State, forming a belt from forty to fifty miles in width. In the eastern part of this belt the rocks are somewhat laminated and slaty, and beds of soapstone are occasionally found. Fossils are rare,

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formation that crowns the bluffs? What is the thickness of this bluff loam? Leaving the bluffs, what breadth of plateau is crossed? What is the character of soil? What geological features are encountered? How are these clays sometimes separated from the bluff loam? What breadth and extent has this formation? What is the character of rocks in the eastern part of it? To what Period and

but it is probable that this formation belongs, in point of time, to the Miocene Epoch of the Tertiary Period. The soil is usually quite fertile. Adjoining the light-colored sands on the east is encountered a new formation, which covers the remaining surface of the section we are describing.

5. This formation consists essentially of beds of siliceous and ferruginous sandstones and marls. At some points, where the country is rolling, and ridges and knobs are presented, the sandstone is found in huge masses and blocks. In some places the sandstone has been crumbled down into beds of light sand, which contain numerous grains of a soft, greenish mineral, sometimes present in such quantities as to give the name of "green sand" to the beds. The green sand beds, which are especially abundant in the eastern part of the formation, are usually calcareous, and sometimes furnish quantities of fertilizing material to the agriculturalist. This formation contains great numbers of fossils, the principal of which are the shells of marine animals, which show the formation to belong to the Cretaceous Period of the Reptilian Age. The soil of this formation is, in general, fertile, but in some places — especially where the country is rough—it is poor.

Epoch does it probably belong? What is the character of the soil? Where and what is the other formation here encountered? What is the character of sand-stone here found? Where it is crumbled, what element does it yield? What fossils does this formation contain? To what Period and Age does it belong? What is the

III. *The Western Valley.*

6. Within the western valley of the Tennessee River there are presented three principal geological formations.

1°. Along the course of the river, extending a short distance on both sides, are alluvial deposits, furnishing a fertile soil with valuable agricultural features.

2°. Along the bases of the ridges which line the valley on both sides, and occasionally extending some distance into the valley itself, are beds of a light-blue limestone, often shaly in character, and occupying a position nearly horizontal. The formation is generally rich in fossils—principally marine shells—which show its age to be that of the Lower Helderberg Period of the Silurian Age.

3°. The main part of the valley proper is covered with thick beds of fine-grained limestones, sometimes argillaceous, and often shaly. The upper beds of the formation are usually of a light-grey color, and the lower are variegated. The beds are, for the most part, nearly horizontal in position. These beds are also very rich in fossils, which are principally sponges and flattened shells of marine origin. The character

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character of the soil? How many Geological formations are presented in the Western Valley of Tennessee River? What is the first? The second? What character has this limestone? Situation? What fossils does it contain? Of what Period and Age? What is the main part of the valley covered with? Of what colors are these? In what position are the beds? What fossils do they

of the fossils proves the formation to be of the age of the Niagara Period of the Silurian Age.

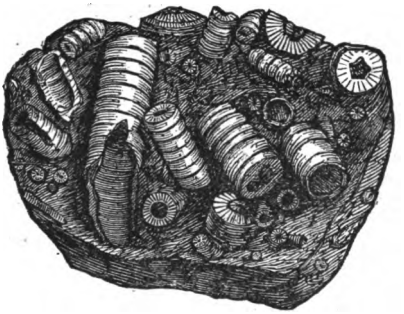

Fig. 13.—Fragment of Encrinital Limestone, Niagara Period.

The smaller valleys of the numerous tributaries that feed the Tennessee River, cutting their channels through the highlands on either side, present the same general geological features as the main valley.

IV. *The Highland Rim.*

7. The entire surface of the Highlands of Middle Tennessee, surrounding the Central Basin on every side, is covered with a series of rocks, which differ somewhat among themselves, but all belong to one and the same formation. These rocks are everywhere characterized by their distinctly *silicious* character; but are sometimes fine sandstones, sometimes silicious limestones, and sometimes silicious shales. A few are

contain? To what Age and Period does this formation belong? What does the illustration represent? With what is the Highland Rim covered? Are they all alike? Do they belong to the same formation? What is the character of these rocks? What varieties

somewhat argillaceous. As a rule, the rocks of this formation are very hard, but furnish, when *weathered*, a soil of considerable fertility. Quartz crystals, geodes, and concretions are frequently found associated with these silicious rocks. The beds in this section occupy a position nearly horizontal. Fossils—principally corals and crinoids—are found in all the beds in greater or less quantities, and some furnish them in great abundance. The characteristic fossil of this formation is a large coral, of peculiar form, which shows the formation to be of the age of the Lower Carboniferous Period, of the Carboniferous Age. By the decomposition of the primitive rocks of this formation, beds of iron ore and of fire clay have been formed in some localities. The fine-grained sandstones are, in some cases, well suited for building purposes. "Sink-holes" are numerous in this section, caused by the breaking through of the hard rock at the surface, and washing away of the softer rocks which underlie it.

V. *The Central Basin.*

8. The Central Basin and the numerous smaller valleys or depressions which occur associated with it,

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do they present? When *weathered*, what do they furnish? What are found frequently associated with them? What position do the beds occupy? What fossils are found in them? Mention the characteristic fossil? What does this show? What have been formed by decomposition in some localities? For what are the grained sandstones suited? How are sink-holes formed? What

in Middle Tennessee, are all possessed of the same general geological features.

9. On descending into the Basin from the Highlands on the west, the outcroppings of several formations are crossed. The silicious rocks, above described, form the cap-rock of the highlands around the Basin. These have a depth facing the descent of seventy-five to one hundred and fifty feet. Immediately below these are found narrow beds of a black, tough shale or slate, presenting a width at this outcropping of fifteen to twenty-five feet. This formation, called the "black shale," underlies nearly the entire State, in beds of various thickness, and outcrops at a great many points. It consists of an argillaceous shale of a nearly black color, and contains a large quantity of bituminous matter, the presence of which causes it to *burn* to some extent when ignited. It is frequently associated with thin layers of argillaceous, concretionary bodies, and fine-grained, bituminous sandstones. The characteristic fossil of this formation is a peculiar *lingula*, (a brachiopod shell), which occurs in considerable quantities, and which indicates that the age of this formation is probably that of the Hamilton

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region presents the same general features? Descending into the Basin, what do we see? What forms the cap-rock of the Highland rim? What depth has this formation? What is found next below? What thickness? The name of this? What extent has it? Of what does it consist? With what is it frequently associated? What is the characteristic fossil of this formation? What does it indicate? What does the shale contain? What does decomposi-

Period of the Devonian Age. The shale contains quantities of iron pyrites and other minerals, which

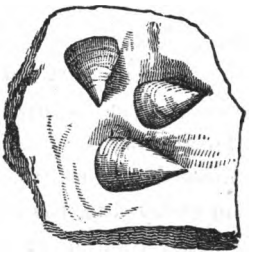

Fig. 14.—Lingula antiqua.

by their decomposition, furnish *alum* and *copperas*, and yield sulphur to numerous sulphur springs, which have their origin in this formation.

10. Immediately below the black shale is found an outcropping of the Niagara limestones, before described, having a width of about seventy-five feet, facing the descent.

11. Beneath this outcropping are encountered beds of a light-colored limestone, which cover the remainder of the slope, and extend a considerable distance, on all sides, into the Basin itself. This formation constitutes one of the principal geological features of this section of the State. The limestones are usually of a light blue color, but sometimes are greenish, yellowish, or dove-color. Occasionally the limestones are somewhat silicious and shaly, producing, on

tion yield? What next is found below the shale? What width or thickness has this formation? Beneath the Niagara limestones what is found? What does this constitute? Describe these lime-

weathering, earthy masses of yellowish or buff color, but this is rare. The rocks of this formation are comparatively rich in fossils, which are of a character to show that, in age, it belongs to the Hudson Period of the Silurian Age. The city of Nashville, the capital of the State, is located upon a bed of blue limestone of this formation.

12. Adjoining these Hudson limestones, and surrounded by them on every side, the entire central part of the Basin is covered by a formation, very similar in the general appearance of its rocks to the one which surrounds it, but differing from it in point of age, as shown by the fossils which it contains. These prove it to belong to the Trenton period of the Silurian Age. The rocks of this formation are mainly blue limestones, sometimes silicious or argillaceous in character, and occasionally shaly. Occasionally, also, beds of red and gray limestones are met with.

13. The rock-beds of the Hudson and Trenton formations, within the Basin, occupy a position nearly horizontal. By their decomposition they furnish a soil of great richness, which renders this section perhaps the most fertile (excepting the river bottoms) of the entire State.

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stones. What do these rocks contain? To what Period and Age do they belong? What City is seated on this formation? What is found adjoining the Hudson limestones? In what respects agreeing with these? In what differing? How is this difference shown? Where do the fossils show it to belong? Describe the rocks of this formation. What position do the Hudson and Trenton formations

14. In passing out of the Basin, going eastward, an outcropping of the black shale is encountered in the line of ascent, immediately overlying the Hudson limestones; the outcropping of the Niagara formation found on the western side of the Basin being absent on the eastern. Above the beds of black shale, occur the silicious rocks of the Lower Carboniferous formation, capping the ridges which line the Basin, and extending eastward, as the surface rock of this part of the Highland Rim.

VI. *The Cumberland Table-land.*

15. This great physical feature of the State consists of a number of strata of rocks of various descriptions, placed horizontally upon each other, forming a huge, massive block of rock material. At certain points these strata have been uplifted and folded over, forming the mountains and high ridges which occur upon the table-land. In ascending from the highland plain below to the top of the table-land, therefore, the edges of these strata, as they outcrop along the steep face of the ascent, will be crossed. As a rule, the succession of the strata, one upon the other, is very regular, and is essentially the same for the greater

occupy? What does their decomposition furnish? Going Eastward, what is encountered? What does this overlie? Is the Niagara formation here found? Above the Black Shale, what occur? What is said of the situation of Silicious rocks? Of what does the Cumberland Table-land consist? What is seen in certain parts of it? What is seen in ascending to the top of the Table-land? Is the succession of these strata regular? Mention the

part of the table-land. The following order is generally observed:

1°. The silicious limestones covering the Highland Rim, at the base of the Table-land, present an additional outcropping, extending from fifty to one hundred and fifty feet up the face of the ascent.

2°. Above these occur beds of ordinary *limestone*, frequently shaly, and occasionally argillaceous. These have a thickness of from one hundred and sixty to two hundred and seventy feet.

3°. A fine-grained *sandstone* next occurs, sometimes laminated and flaggy, and from ten to fifty feet in thickness.

4°. Beds of *blue limestones*, sometimes argillaceous and shaly, from ninety to one hundred and seventy feet in thickness, are next in order of occurrence.

5°. *Argillaceous limestones*, fine-grained, and of a bluish-gray color, usually interstratified with beds of shale, are next above, in beds from sixty to one hundred and fifty feet in thickness.

6°. Marls and shales, variegated in color, with occasionally a layer of limestone, next occur, in a deposit from fifty to one hundred and thirty feet thick.

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order in which these occur. The first? What extent up the face of the ascent does this occupy? What next occurs, ascending? What thickness? What is found, thirdly, in ascending? Of what thickness? Describe it? What fourth? Describe them? Fifth? Describe them. What thickness has the Argillaceous Limestone? In the sixth place, what is found? What depth of deposit?

7⁰. A stratum of crinoidal limestone, with more or less shale, is next above, from four to seventy feet in thickness.

The beds of rocks thus far described, lying above the silicious limestone first mentioned, are generally classed together, forming a group called the "Mountain Limestone Group." They are generally rich in fossils, which show them to belong to the Lower Carboniferous Period of the Carboniferous Age.

Above the mountain limestone, there are outcroppings of a number of different strata to be crossed before the top of the table-land is reached. These, taken together, constitute, in general, three groups, occurring in the following order:

8⁰. A group called the "Lower Coal Measures," consisting of alternate beds of *sandstones* and *shales*, with thin seams of *stone coal* occasionally interstratified. The thickness of the entire group varies from ten to three hundred feet.

9⁰. A group called the "Conglomerate," consisting of several strata of silicious rocks, generally abounding in small, rounded, white, quartz pebbles. This group usually forms the surface of the Table-land immediately about the cliffs and crested edges at the top of the slope of ascent, extending back—as the

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What seventh, and of what thickness? What are these seven formations, classed together, termed? To what Period and Age do they belong? Above the Mountain Limestone, what next? How many groups must be crossed before reaching the top? What is the eighth group called? Describe it. What the ninth? Of

surface—to a greater or less distance from the bluff margin.

10°. Resting upon the conglomerate, and forming the main top-surface or *floor* of the Table-land proper, is a group called the "Upper Coal Measures," consisting essentially of several strata of sandstones, interstratified with frequently occurring beds of shale and clay, with numerous seams of *stone coal*, and, occasionally, thin beds of crinoidal limestones. The thickness of the entire group is from two hundred to three hundred feet.

The three groups just described, taken together, constitute a formation known as the "Coal Measures." They afford numerous fossils and other indications, which show that this formation belongs to the later periods of the Carboniferous Age, probably, in most part, to the Carboniferous Period.

This formation is the source of all the coal found in the State. The seams of coal generally vary in thickness from a few inches to six or eight feet.

The mountain ranges which occur on the Table-land were formed by the folding over, in anticlinal ridges, of the strata and formations above described. Frequently, in these ranges, outcroppings occur of the

what does the Conglomerate consist? What does this form? How far does it extend? What is found in the tenth place? Upon what does it rest? Of what do the Upper Coal Measures consist? What is the thickness of these? What are these three groups, taken together, called? What do they afford? To what Period and Age do these belong? Where is all the coal of the State found? Of what thickness are the seams? How were the mountain-ranges

strata which underlie the flat surface of the Table-land proper.

The Sequatchie Valley, which cuts through the Table-land in the form of a long, narrow gorge, exposes outcroppings of the strata above mentioned, and, in its lower, or *bottom* portion, has much the same geological formation as the Central Basin.

VII. *The Valley of East Tennessee.*

In descending from the Table-land on the eastern side, nearly the same alternations of strata are encountered as were found outcropping on the western side. When the bottom of the descent is reached, and we come into the Valley of East Tennessee, we find a region presenting great diversity in geological features. In this section all the strata dip from the surface with angles of steep inclination, so that in crossing the country, we travel over the edges of numerous outcropping strata. The greater part of these outcroppings, however, are not of different strata, but of the same strata, coming to the surface at different points, a number of them being folded under the surface in many places in the form of synclinal folds. Without classifying the strata in the order in which the out-

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of the Table-Land formed? What frequently occur in them? What form has Sequatchie Valley? What does it expose? What geological character has its lower portion? Descending from the Table-Land Eastwardly, what is found? What is reached at the bottom of the descent? What do we find presented? What position characterizes the strata of this region? How do we travel over them? Are these edges of different strata? What are they?

croppings occur, we may mention the character of the principal rocks which occur in this section.

By far the greater part of the surface is made up of the outcroppings of rocks which, judged from the fossils which they yield, and other indications, belong to the Potsdam Period of the Silurian Age. They are, therefore, very old rocks. The rocks of this formation are mainly of three kinds, viz: sandstones, shales, and dolomites, (magnesian limestones). This threefold character of the rocks is well exhibited in the region immediately about the city of Knoxville, hence the name "Knox group" has been applied to them.

The *Knox Dolomite* occupies much the largest part of the surface of the Valley. It is a light grey, fine-grained rock, sometimes light blue or variegated in color. When massive, it is frequently wrought for marble and building stone. It is sometimes argillaceous and shaly, and occasionally is weathered to a loose sand. It yields many fossils of distinct types. The beds are, as a rule, of great extent and thickness. The land above these rocks is very fertile.

How formed? What will be mentioned of them? What makes up the greater part of the surface? By what shall we judge their age? To what Period and Age do they belong? Are they old rocks? Of how many kinds are they? What are these? Where is this character well exhibited? What name for this group is hence applied? What occupies the greater part of the valley's surface? Describe the Knox Dolomite? For what is it wrought? In what other forms is it seen? What fossils has it? What is said of the beds? How is the land above them? Of what does the

The *Knox Shale* consists of beds of argillaceous shale of variegated appearance, generally interstratified with thin layers of oolitic limestone and dolomite. It is usually a soft rock, easily weathered, and forming a fertile soil.

The *Knox Sandstone* consists essentially of heavy, massive sandstones, both fine and coarse-grained, associated with thin layers of hard shales and fine sandstones. The heavy sandstones are sometimes quartzose, and occasionally contain green grains. The rocks are sometimes *jaspery*, and often yield beautiful specimens of jasper and chalcedony. Ripple marks and evidences of beach-structure are occasionally found. These rocks are usually of great thickness.

The rocks of the three divisions of the Knox group, above described, sometimes occur associated together, forming the surface of the Valley, but are frequently separated from each other by strata belonging to other formations.

Next in importance to the rocks of the Knox group, there are presented in this section outcroppings of the limestones and shales of the Trenton and Hudson formations, (elsewhere described), which occur at intervals, as we cross the Valley, traveling from west to east. These outcroppings are sometimes of great width—especially in the western part of the

Knox Shale consist? What is said of its properties? Of what does the Knox Sandstone consist? What beautiful specimens do they yield sometimes? What marks are sometimes found on them?

Valley—and sometimes are narrow seams of little extent.

In addition to those described above, rocks of the Niagara, Lower Carboniferous, Black Shale, and other formations, also occur, to a slight extent, outcropping in the Valley.

VIII. *The Unaka Chain.*

The rocks which make up the great masses of high mountains, ridges, and elevated plains in the extreme eastern part of the State, which we have grouped together under the name the "Unaka Chain," may be divided into two classes—the *stratified* and the *metamorphic.*

1. The stratified rocks are mainly sandstones, conglomerates, and slates, and were all formed during the same period of time, viz: the Potsdam Period of the Silurian Age.

The sandstones are a very marked feature of this section, and consist of heavy, massive sandstones, often dark, but generally a light gray, and containing great beds of light-colored quartzite. Sandy shales and thin flags are often interstratified. Some of the sandstones are coarse, and resemble fine conglomer-

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Are these rocks thick? How do these three divisions sometimes occur? How otherwise? What next in importance are found? What is said of the width of these outcroppings? What other rocks occur to a slight extent? What is meant by the Unaka chain? Into what classes may these rocks be divided? Of what are the Stratified rocks composed? To what Period and Age do they belong? What is said of the Sandstones here? Of what do

ates. Worm holes and sea-weed impressions are the fossils which they yield in great numbers. The sandstones constitute the surface rock of a number of the great mountains.

The conglomerates are silicious and generally form massive beds, containing coarse pebbles of quartz and feldspar. Occasionally they are of finer texture. Particles of chloritic and talcose slates are frequently found imbedded in the conglomerate.

The slates usually occur in beds alternating with the conglomerates. They are principally talcose and chloritic, of light colors—blue or greenish.

They are essentially argillaceous, and occur in thick, heavy beds, occasionally associated with a thin layer of limestone or calcareous pudding-stone. The weathering of the slate furnishes, at some points, beds of clay, and sometimes, of quartz sand. Many of the highest mountains of the State are made up entirely of the conglomerates and slates above mentioned.

A massive structure is characteristic of the rocks of this section.

2. The metamorphic rocks occupy a very limited area in the State, and are confined to very small sections which occur along the eastern border of the Unaka Chain. They are found at no other point in

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they consist? Describe them. What do they contain? What are often inter-stratified? Describe some of these sandstones. What fossils? What do these sandstones constitute? Describe the Conglomerates? How are they found occasionally? What is frequently found imbedded in this Conglomerate? How do the Slates

the State, but occur to a considerable extent beyond the State line in North Carolina.

The rocks, which are crystalline and occur in stratified beds, are chiefly *gneiss*, *mica-slate*, and *talcose-slate*. They are sometimes *syenitic*. The position of the rocks and other considerations, indicate that they are of the same age as the sandstones, slates, etc., which adjoin them, and from which they were probably formed, by metamorphic action.

These rocks furnish some of the most important minerals and ores found in the State. The Ducktown Copper Mines, in Polk County, are located in the metamorphic rocks.

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occur? Of what kinds are they? What are they, and how do they occur? What does the weathering of the slate furnish? Of what are many of the highest mountains formed? What characterizes the rocks of this Section? What is said of the area and limit of the Metamorphic rocks? Are they found elsewhere in the State? Beyond it? What rocks are crystalline? How do they occur? What character have these rocks sometimes? How is their age indicated, and what is their age? How were they probably formed? What do these rocks furnish? What important mines are located in them?

CHAPTER IX.

DYNAMICAL GEOLOGY.

We come now to examine the agencies which, operating through a long series of ages, have given to the State the rock beds, formations, and physical features we have described. That branch of geology that treats of the changes that occur in the crust of the earth, and of the causes or agents which produce those changes, is termed Dynamical Geology.

As has already been in part explained, the three great agencies that have acted in times past to modify and change the character of the surface of the earth, are Heat, Water, and Life. These agencies are even now at work, producing the same character of changes in the present crust of the earth.

I. *Heat.* It is the great heat of the interior of the earth that has been especially active in producing changes and modifications of the surface. The existence of a very high temperature in the interior, beneath the crust of the earth, is proven by a number of natural phenomena, such as the eruptions of volcanoes, geysers, hot springs, the increase of temperature with increase of depth in the rocks of the crust, the crystalline character of the lowest rocks, &c.

What do we propose to examine next? What does Dynamic Geology treat of? What great agencies modified the earth's surface? Are they at work now? What has the interior heat of the Earth effected? How is great internal heat of the Earth proven?

The effects of heat have been both *formative* and *destructive.* The formation of the first dry land, by the cooling of melted rocks, has already been described. New surface rocks have subsequently been formed by ejections of melted mineral matter from the interior, producing the *igneous rocks* before described.

The *modifying* and *destructive* effects of heat are more important and noticeable in the structure of the earth's crust. The great mountain chains and the corresponding deep valleys, the folded and tilted strata with their great displacements and faults, have probably been in great part produced by vast and mighty upheavals, caused by the expansion, by heat, of gaseous matter (as water in the form of steam, &c.) within the interior of the earth.

The change of sedimentary rocks to the condition of metamorphic, was due to the direct action of this internal heat.

II. *Water* That water has played an important part—much more important than any other agency—in the structure of the surface of the earth, is evident from the great proportion of the rocks which are sedimentary or stratified in character. Water has been both formative and destructive in its action. The

What two effects have resulted from heat? What has been already described? What were subsequently formed, and how? What are these rocks termed? What and how are the modifying and destructive effects of heat seen? What changed sedimentary rocks to Metamorphic? What part has water played in characterizing the Earth's surface? From what is this evident? What two effects has the action of water exerted? In what forms has water

chief forms in which water has exerted its power upon the rocks of the globe are, as rain-water, the water of rivers, lakes, and seas, and frozen water, or ice.

The chief action of rain-water has been in the "weathering" of the rocks, beating them down, and, by its solvent action, disintegrating them and decomposing their mineral constituents; thus destroying the massive rocks, but, at the same time, frequently forming beds of clay or fine sand. All the "soil" which covers the major part of the dry land of the earth, has been formed by such a weathering of the hard rocks which underlie it. The action of rain-water in forming caves, &c., in limestone regions, has been already spoken of.

Rivers and smaller streams of running water exert their power in *eroding* and washing away the rocks over which they flow. Denuded strata, extensive valleys, river channels, gorges, canyons, &c., have been formed in this way. When the rocks over which a river flowed were of unequal hardness, the softest would be washed away first, leaving the others, thus producing striking features in the face of the country. The rivers also transport, or carry down with them in their course, the mineral matter which they have

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exerted its power? What has been the chief action of rain water? What effect has this had on the massive rocks? What have these materials formed at the same time? How has most of the soil of the earth been formed? What other action of rain water has been noticed already? How do rivers and smaller streams exert their

washed away from the rocks above. A portion of this they deposit in the valleys through which they flow, forming *alluvial* beds, thus bringing the material of the hills to fill the plains. A portion they carry to the seas or lakes into which they empty, where it forms, by the combined action of the waters, *deltas* and other sea-shore accumulations about the mouths of the rivers.

The seas present water in its most powerful form for action upon the land. In this form it has had most influence in shaping the character of the earth's surface. These large bodies of water, beating—through the motions of powerful waves and currents—upon the shores of the continents and bodies of land exposed to their action, break them down and gradually wear them away. The fine mineral matter thus gathered by the sea from the land is deposited at its bottom, usually near the land-shore, or thrown back towards the shore by the currents and waves, thus forming extensive *beaches.* In the case of shallow seas sweeping over great surfaces of submerged continents, extensive beds of sedimentary rocks, formed of the mineral matter gathered by the seas from the dry land of their shores, have been deposited at their bottoms. The depths of the seas, and their

power? What have thus been formed? Flowing over rocks of unequal hardness, what effect would result? What do the rivers transport in their course? What is done with this mineral matter? When carried to the seas, what are formed? What do the seas present? What great influence have the seas had? How? What is deposited at the sea's bottom? Where, usually? Forming

conditions of quietness or activity, influence the character of these deposits. Shallow seas have also furnished the dwelling places for myriads of marine animals, which, on their death, yielded shells and other parts of their structure to the waters, to be deposited by them in the form of beds. It is through the agency of such shallow bodies of water that the greater part of the stratified rocks have been formed.

The waters of lakes, and inland bodies of water, have performed the same offices as the seas when they were large, and as the rivers when they were of smaller extent.

Frozen water, or ice, has had its action upon the surface of the earth principally in two forms—as glaciers and icebergs. Glaciers are streams or *rivers* of frozen water, extending in long, narrow channels from the high regions of the snow-crowned mountains to the valleys and plains below. In their descent, these bodies of ice follow the same general course as bodies of liquid water would pursue under the same circumstances; they, in fact, *flow*, or pass slowly down their course, a part of the ice continually melting in the warm valleys below, its place being supplied by constant additions from the snow regions above. The

what? Doing what in shallow seas? What conditions have influenced these deposits? What have shallow seas furnished? Through what agency was stratified rock chiefly formed? In what cases have inland lakes done the same? In what forms has ice exerted its power? What are glaciers? Descending, what course do they follow? How do they pass down their course? By what process do they *flow*? How is the waste by melting supplied?

glaciers erode and wear away the surfaces over which they pass. They carry the material they thus gather, together with such masses of rock and earth as may have fallen upon them from overhanging cliffs, to the valleys below. There they deposit it, on melting. They thus transport the materials of the mountains to the plains. Icebergs are huge masses of ice which have become detached from such glaciers as empty their frozen waters into the sea. These masses, frequently of immense size, float on the bosom of the seas, and are transported by the currents to warmer regions, are melted, depositing their burdens of rock-material, gathered when they were part of the glacier, at the bottom of the seas. The action of frozen water is thus also both destructive and formative.

III. *Life.* The shallow seas of past geologic ages swarmed with animal life of various types and forms. These, in the course of their life and growth, *secreted* from the waters various mineral matters (chiefly calcareous and silicous) washed by the sea from the land, and used them in the formation of their shells, bones, and other stony parts. As the animals died, their skeletons sank to the bottom of the sea, and formed, in the course of time, of their great number, beds of

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How do glaciers act on surfaces? How and where do they deposit rocks and earth? What do they transport to the plains? What are icebergs? Are they large? Where and how are they carried? When they melt, what do they deposit? What double action has frozen water, thus? What is said of life in early shallow seas?

rocky material. The waters, beating upon this material, first ground it to a fine powder, in most cases, then aggregated it, and finally, by pressure, consolidated it into a bed of true sedimentary rock.

The animals chiefly concerned in this secretion-process were Mollusks, Radiates, and Rhizopods, forming calcareous rocks, and Diatoms and Protozoans yielding silicious material. By far the greatest number of rocks formed in this manner are calcareous. Probably all the varieties of sedimentary limestones are of this origin.

Plant-life has also contributed its share to the formation of the rocks. At certain periods of geologic time, plants have grown in great luxuriance and to great size, forming extensive and dense forests and thickets. As the plants died, their trunks and frames decayed and crumbled to the earth. There came to be formed, therefore, in many places, immense beds, or deposits, of decaying vegetable matter. Such deposits are now frequently seen, in a primitive condition in marshy localities, and in a more advanced state, forming beds of peat. As the decay continued, and the beds increased in thickness, great pressure was brought to bear upon them, probably by their

What did these types of life do? What happened as these animals died? How did the waters, beating on these skeletons, affect them? Into what was this matter consolidated? What animals were chiefly concerned in this process? What kinds of rocks are thus formed? What agency has plant-life exerted? What is said of plant-luxuriance? What became of dead plants? What thence were formed? Where are such formations now to be found? How

subsidence beneath the waters of some inland sea, and the subsequent deposits upon them of other rock material. This pressure consolidated the decayed, woody matter, and formed stratified beds of the various kinds of mineral coal.

It appears evident that, during the operations of the agencies above described, there was going on, in addition to the occasional sudden and violent upheavals of the earth's crust already mentioned, a slow and gentle *oscillation* of the crust—subsiding in some places and elevating in others—which continually presented new conditions for the exercise of these agencies. Such a gentle oscillation is going on at the present time.

This continuous and persistent motion in the crust of the earth—slowly sinking the bottoms of the seas at some points, and raising the surface of the dry land at others, thus producing changes in the features of the surface at different periods of time—has played a very important part in influencing and modifying the actions of the agencies described above, and in giving to the surface of the earth its rocks and physical features.

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in a more advanced state? How was great pressure brought to bear on them? What effect had this pressure? What was going on during this process? What in addition thereto? Was this uniform in all places? What is going on at the present time? What has this persistent motion done? What important part has it played? What has it given to the earth's surface?